THE RESOURCES AGENCY OF CALIFORNIA

Department of Water Resources

BULLETIN No. 99

RECONNAISSANCE REPORT ON UPPER PUTAH CREEK BASIN INVESTIGATION

MARCH 1962

EDMUND G. BROWN
Governor
State of California

WILLIAM E. WARNE
Administrator
The Resources Agency of California
and Director
Department of Water Resources

1. The community of Middletown. The largest populated community in the Upper Putah Creek Basin is located between St. Helena Creek (foreground) and Putah and Dry Creeks (background).

STATE OF CALIFORNIA
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DEPARTMENT OF WATER RESOURCES
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February 27, 1962

Honorable Edmund G. Brown, Governor,
and Members of the Legislature
of the State of California

Gentlemen:

I have the honor to transmit herewith Bulletin No. 99 of the Department of Water Resources, "Reconnaissance Report on Upper Putah Creek Basin Investigation", authorized under Item 256 of the Budget Act of 1960.

This bulletin contains basic data and information which identifies the water problems of the area, and includes reconnaissance appraisals of various possibilities for development of additional surface and ground water supplies within the area. It recommends that local interests continue to proceed with development of their water resources as fast as is economically possible, so that the possibility for the loss of right to appropriate water, which would be induced by the culmination of the Monticello Project, will be kept to a minimum. To that end, the information presented in this bulletin should serve to help the local people understand the nature and extent of their water problems and to reach agreement on the necessary steps that should be taken toward their solution.

Sincerely yours,

William E. Warne

Director

ACKNOWLEDGMENT

Valuable assistance and data used in the investigation were contributed by agencies of the Federal Government, the State of California, cities, counties, and by private companies and individuals. This cooperation is gratefully acknowledged.

Special mention is made of the helpful cooperation of the following:

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California Department of Natural Resources, Division of Mines

California State Water Rights Board

Geological Survey, United States Department of the Interior

Lake County Flood Control and Water Conservation District

Middletown County Water District

Napa County Agricultural Commissioner's Office

Napa County Farm Advisor's Office

Napa County Planning Commission

Sacramento County Farm Advisor's Office

Soil Conservation Service, United States Department of Agriculture

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UPPER PUTAH CREEK BASIN INVESTIGATION

CHAPTER I. INTRODUCTION

The upper Putah Creek Basin, shown on Plate 1, "Location of Upper Putah Creek Basin" is located in the southerly portion of Lake County and the northerly portion of Napa County. Putah Creek has recently been developed to a very significant degree by Monticello Reservoir (Lake Berryessa), the key unit of the Solano Project, constructed and operated by the United States Bureau of Reclamation. About 87 percent of the mean seasonal unimpaired runoff originating in the Upper Putah Creek Basin has been developed by this reservoir. The reservoir is a multiple-purpose development designed to supply water for an extensive agricultural area, municipal and industrial uses, and for national defense establishments in Solano County. Provision has been made for development of hydroelectric power at a future date.

Despite the high degree of development brought about by Monticello Reservoir, water supplies available for local use in Upper Putah Creek Basin above Monticello Reservoir are developed to a very limited extent. Development of both surface and underground water resources is needed if this area is to prosper and grow along with other parts of California.

A recent ruling by the State Water Rights Board[1/] placed a time limitation on the acquisition of water rights by intending

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1/ State Water Rights Board Decision No. 869, Feb. 7, 1957 appropriators. If local water resources in the Upper Putah Creek Basin are not developed prior to full beneficial use of Monticello water in the Solano Project service area, the right to develop additional water supplies which are subject to the laws of appropriation will presumably be lost forever. There is, therefore, a need for immediate planning for water resource development.

Authorization for Investigation

The Water Rights Board ruling brought to a head the need for an orderly program of local water resource development, which had long been desired by local interests. Shortly after the decision was handed down the Boards of Supervisors of Lake and Napa counties individually requested state assistance in an investigation of water development possibilities in the Upper Putah Creek Basin. The California legislature, in the Budget Act of 1960, appropriated $48,000 for the Department of Water Resources to conduct a one-year reconnaissance investigation. The investigation was conducted during the 1960-61 fiscal year under the authority contained in Sections 225, 226, 227, 12616, and 12617 of the Water Code, and the legislative appropriation.

Objective and Scope of the Investigation

The broad objectives and scope of the investigation were defined on March 2, 1960, in a letter to Mr. A. Alan Post, Legislative Analyst from Mr. Harvey O. Banks, who was Director of Water Resources at that time. The letter stated in part:

". . . for a limited scope investigation . . . the objectives of the investigation would have to be confined to developing only enough basic data and information to identify the water problems of the area to arrive at conclusions as to additional steps that should be taken toward their solution.

"Following is a work program for a limited scope investigation that could be completed in one year.

"1. Prepare reconnaissance estimates of unregulated water supplies at locations in the Putah Creek stream having potential for water development.

"2. Prepare reconnaissance estimates of water needs, and their location and character.

"3. Inventory possible surface reservoir sites. This would include reconnaissance geologic evaluations of dam sites, preliminary surveys of the sites, and rough estimates of costs and possible reservoir yields for various volumes of storage.

"4. Make a reconnaissance appraisal of the ground water potential. Included would be a summary of present uses of ground water, existing well records and yields, and a geologic reconnaissance of the ground water basins.

"5. Make a reconnaissance study of agricultural economics in the area.

"6. Prepare a preliminary appraisal of local interest in water development, and the possibilities for financing and constructing water development works.

". . . prepare a report summarizing results of the investigation, with conclusions and recommendations for a subsequent course of action."

The report is <u>not</u> intended to present a comprehensive analysis of all aspects of water resources problems in the Upper Putah Creek Basin nor does it present a specific plan for water development. It does supply data which will aid the local people in plotting a course toward water development.

Related Investigations and Reports

In connection with this investigation, a review was made of several reports and basic data of prior investigations dealing with various phases of water resources problems of the Upper Putah Creek Basin. A brief summary of the content of the reports most significant to this investigation follows.

Putah Creek Cone Investigation

This investigation, conducted by the California Division of Water Resources commenced in September 1951. The completed report, "Report to the California State Legislature on the Putah Creek Cone Investigation" was issued in December 1955. The investigation had as its principal objectives the determination of surface and underground water supplies and present and future utilization of these supplies in the Putah Creek Cone Area of Solano County. With the start of construction of Monticello Dam of the Solano Project by the United States Bureau of Reclamation in 1953, studies necessary for solution of the water right problems became of prime importance. These water right studies proved to be the basis for the Water Rights Board ruling which made the bureau's permits at Monticello Reservoir subject to future appropriation of water for beneficial use in the Upper Putah Creek Basin. The report contains data on water supply, precipitation, runoff, and ground water originating in the Upper Basin and estimates of present and possible future land and water use by irrigation in the Upper Basin. Plans for developing additional water supplies for use in the Upper

Putah Creek Basin were not included as part of the Putah Creek Cone Investigation.

Investigation of Ground Water of the Lower Lake-Middletown Area

This investigation, conducted by the United States Geological Survey in cooperation with the California Division of Water Resources, commenced in June 1950. The completed report, "Ground Water of the Lower Lake-Middletown Area, California", was published as U. S. Geological Survey Water-Supply Paper 1297 in 1955. Although the larger part of the area covered by this investigation is located in the Cache Creek Basin, existing ground water conditions and possibilities for increased development in Collayomi, Long, and Coyote Valleys near Middletown in the Upper Putah Creek Basin are included in the report. The results obtained from this reconnaissance investigation were considered preliminary because of the limited extent of development and general paucity of data available at that time.

State Water Rights Board Decision No. 869

This document is the official decision and resulting order of the Water Rights Board regarding the U. S. Bureau of Reclamation applications 11199, 12578, and 12716 to appropriate unappropriated waters in Putah Creek at Monticello Reservoir for use in the Solano Project service area. It provides a documented history and consideration denied by the State Water Rights Board Decision No. 869 of evidence presented at the water rights hearings on the aforementioned applications.

State-Wide Water Resources Investigation

The State-Wide Water Resources Investigation, directed by the State Water Resources Board and conducted by the California Division of Water Resources, was initiated in 1947 and completed in 1957. Three bulletins were published containing the results of this investigation. Bulletin No. 1, "Water Resources of California", published in 1951, contains a compilation of data and estimates of precipitation, unimpaired runoff, flood flows and frequencies, and quality of water throughout the State. Bulletin No. 2, "Water Utilization and Requirements of California", published in June 1955, includes a determination of present and probable ultimate consumptive use of and requirements for water throughout the State. The third and concluding phase of the investigation was reported in Bulletin No. 3, "The California Water Plan", published in May 1957. This bulletin presents a comprehensive master plan to serve as a guide to the full practicable development of the water resources of the State to meet future beneficial needs of the State. The relatively large projects proposed in Bulletin No. 3 for development of water for use in the Upper Basin although practicable, would probably be difficult to finance under present economic conditions.

Other Sources of Data

Other reports and sources of information containing valuable data on various phases of water resources problems of the Upper Putah Creek Basin were reviewed and utilized as part of this investigation. These are listed in Appendix B, "Bibliography".

The Area and the Problems

The area under investigation comprises the lands within the Putah Creek watershed above Monticello Reservoir (Lake Berryessa). The foremost problem concerning water development that now confronts the area is the limited time available to appropriate and develop additional water supplies for future needs of the area.

The Area Under Investigation

The Upper Putah Creek Basin is a generally mountainous area of about 568 square miles. It is located in the southerly portion of Lake County and the northerly portion of Napa County. The area is about 45 miles in length and about 20 miles in width at the widest point. The basin is bounded on the east and northeast by the Blue Ridge Mountains, which also form the boundary separating Napa County from Yolo and Solano Counties. It is bounded on the south and southwest by the Howell and Mayacmas Mountains; and on the west and northwest by ridge tops that separate the Cache and Putah Creek drainage basins.

Elevations along the basin rim range from 1,500 to 3,500 feet. The southwest rim is dominated by Cobb Mountain and Mount St. Helena which reach elevations of 4,722 feet and 4,344 feet, respectively. The highest point on the northeast rim is Berryessa Peak with an elevation of 3,046 feet. The higher elevations, principally along the west and southwesterly portion of the watershed, are covered with dense stands of conifer and white oak. The lower slopes generally support only a sparse forest of scrub pine, oak, chaparral, and manzanita. The lowest elevation in the basin is the water surface of Lake Berryessa which ranges from about 253 feet when empty to 440 feet when full.

Putah Creek is fed by ten major and several minor tributary streams, along which are located numerous valleys comprising the cultivable lands in the basin. The principal tributary streams entering Putah Creek from the north are Eticuera, Hunting, Soda, and Big Canyon Creeks. Dry, St. Helena, Bucksnort, Butts, Pope, and Capell Creeks comprise the principal tributaries draining the southerly portion of the watershed. The total irrigable area comprises only about eight percent of the total land area in the basin. The major potential agricultural areas are located in or near Collayomi, Long, and Coyote Valleys along the upper reaches of Putah Creek, in Pope Valley along Pope and Maxwell Creeks, and in Capell Valley along Capell Creek. Numerous minor arable areas are situated along Hunting, Soda, and Butts Creeks and the lesser tributaries.

The agricultural soils of the Upper Putah Creek area are quite variable. This variability is the result of the mode of formation and the degree of development of the soil profiles. Three major soil groupings can be identified: recent alluvial soils, older alluvial or terrace soils, and upland soils. There is an approximately equal acreage of each of the three soil groups in the area.

The recent alluvial soils have the most agricultural value. Soil profiles are typically well-drained, friable, and deep enough to allow for the cultivation of all climatically adapted crops.

The older alluvial or terrace soils show the modification of time which has caused the formation of rather tight and impenetrable subsoil layers. These layers restrict plant root development and water movement, leaving the soil suitable for the production of only shallow root crops such as pasture, grain, and a select few truck and field crops.

The third grouping is the upland soils. These soils generally have the least agricultural value. The soil mantle was formed in place from the weathering of the sedimentary parent rock material. Shallow soil depth and extreme relief generally restrict the crop adaptability to pasture and a few orchard crops.

The climate of the Upper Putah Creek Basin is of the mild two-season pattern. A warm, dry season usually extends from May through September, with a cool, wet season from October through April. Mean seasonal precipitation varies from a minimum of about 22 inches near Lake Berryessa to over 80 inches at the higher elevations. Rainfall constitutes practically all precipitation in the area. Snowfall is rare, except at the higher elevations, and is too small to have any significant effect on the hydrologic characteristics of stream flow. Over 95 percent of the precipitation occurs during the period from October through April. The growing season is relatively long, with an estimated average of 250 days between killing frosts.

The majority of runoff occurs immediately following the rainfall but is prolonged somewhat by the accretions to streams from retained soil moisture. In general, stream flow diminishes to negligible amounts during the late summer and fall months. However, there are numerous springs that maintain a limited flow throughout the summer and provide water for domestic, stock watering, and recreational purposes. In addition to intraseasonal fluctuations, runoff has a wide annual variation, largely depending on the amount of annual precipitation. The estimated mean annual runoff from the Upper Putah Creek Basin is about 348,000 acre-feet.

Recent development in the basin began when the first white settlers arrived about the middle of the nineteenth century. At that time the land was inhabited by Indians who lived in several of the valleys. Shortly after 1900, tuberculosis, smallpox, and measles, rapidly wiped out most of the Indians. Development of the Upper Putah Creek Basin has progressed slowly. Farming and recreational industries are the major economic interests. In the past, the mining industry attracted prospectors and developers to the area, but today, mining plays a much lesser role in the economy of the area. Mercury production is now the most important mining industry.

Agriculture was begun by the first white settlers; livestock and grain were the earliest farm products. The first record of irrigation in the basin was reported by the U. S. Department of Agriculture in 1912, when about 340 acres were irrigated. After that time, development of irrigated agriculture progressed more rapidly. It was estimated by the Department of Water Resources that there were about 3,300 acres of irrigated crop lands in 1947. This acreage was reduced to about 1,800 acres in 1957, when Berryessa Valley was inundated by the creation of Lake Berryessa. During 1960 about 2,600 acres were irrigated and dry farming took place on 5,500 acres of cultivated land.

Recreation development began as early as 1852 when a resort was established at Harbin Spring near Middletown. In the years that followed several more mineral spring resorts were developed, principally in the upper reaches of the basin and along the top of the westerly ridge. Today, changing customs and the completion of Lake Berryessa have made water sports, fishing, and hunting the major attractions in the basin. Lake Berryessa lies in a beautiful, oak-studded valley in the foothills bordering the west side of the Sacramento Valley just 2-1/2 hours from the San Francisco Bay area and one hour from the Sacramento Metropolitan area.

Along the west shore of Lake Berryessa about 3,700 acres of federal land are administered by Napa County under a 50-year lease from the Bureau of Reclamation. The county, in turn, has granted 20-year subleases on portions of this land for private resorts and concessions, under the supervision of the Lake Berryessa Park Commission. The east shore of the lake is privately owned, and no public bank fishing or picnicking is permitted there. There are several resorts along the west shore. Most have a launching ramp, marine gasoline, facilities for boat storage, a restaurant or snack bar, campsites, and picnic areas. Some have boat and motor rentals. According to U. S. Bureau of Reclamation records, about 845,000 visitor-days of use occured at the reservoir during 1959. However, about 70 percent of these visitors were principally sight-seers and did not use the facilities available.

2. Helen Mine--an inactive quicksilver mine located near the head-waters of Dry Creek.

3. An active mine in the Upper Putah Creek Basin. Mercury production still continues in the area.

Today, the Lake County portion is the most heavily populated part of the basin with about 75 percent of the estimated present population of 1,200. The principal urban center is Middletown, an unincorporated community of about 450 residents in Lake County along the upper reaches of Putah Creek and its tributaries. The estimated 300 residents in the Napa County portion of the basin are mainly located in Pope and Capell Valleys and along the western shoreline of Lake Berryessa.

The Principal Problems

In the past, growth in the Upper Putah Creek Basin has been dependent upon and limited by the development of its water resources. Future growth in the area - whether it be agricultural, industrial, urban, or recreational - will continue to be dependent on development of adequate and dependable water supplies. Although the quantity of water originating in the Upper Putah Creek Basin greatly exceeds all possible beneficial uses which may reasonably be anticipated in the basin, there are numerous problems which must be solved before additional water can be developed in significant quantities.

Because of its semiarid climate, the Upper Putah Creek Basin experiences natural surface water deficiencies during the summer and fall months when rainfall is small and runoff is meager. This seasonal deficiency is intensified by prolonged periods of drought when both rainfall and runoff are below normal. To solve the problem of seasonal and cyclic fluctuation of runoff in developing a firm and reliable source of water supply for beneficial use, significant quantities of

4. A concrete aggregate plant located on Putah Creek in Collayomi Valley near Middletown.

5. Cattle grazing in Pope Valley. Here, as elsewhere in the basin, much of the valley areas are presently used for range land.

storage capacity are required. Storage capacity can be made available by the construction of surface reservoirs or through the development of ground water. The problem is to determine which method or combination of methods is most suitable.

The determination of the most suitable method or methods is dependent on physical, economic, and legal factors. Physical factors include water requirements, sources of water, and facilities necessary to develop the sources of water to meet the water requirements. Economic factors include the cost of constructing and operating the required facilities, the value of water, and the means of securing funds to meet these costs. Legal factors include the problem of securing adequate water rights.

Adequate water rights are a necessary prerequisite to the construction and operation of any water development project - whether large or small - which involves the diversion or storage of surface water for use on nonriparian land. The recent ruling by the State Water Rights Board regarding the water right permits at Monticello Reservoir limits future appropriation of local water for use in the upper basin above Monticello Reservoir. The maximum amount of water to be taken by future appropriation is fixed by a provision that the water rights granted for the Solano Project shall be subject to a depletion of stream flow above Monticello Reservoir, not to exceed 33,000 acre-feet of water annually. In addition a limitation is placed on the time available for this future appropriation. The terms of the water rights permits require that the future appropriations must be initiated and

6. Recreation development along the west shore of Lake Berryessa. This area has facilities for picnicking, camping, and boat launching and storage.

7. A small marina on Lake Berryessa, where development of recreation is steadily increasing.

consummated prior to full beneficial use of water from Monticello Reservoir in the Solano Project service area. Therefore, the problems of water development in the Upper Putah Creek Basin include the problem of time available to appropriate additional water.

The following chapters of this report discuss the various facets of the water problems in detail and form a source of basic data. These data will be helpful to local people interested in solving their water problems.

CHAPTER II. WATER UTILIZATION AND REQUIREMENTS

The nature and extent of water utilization in the Upper Putah Creek Basin at the present time and the future requirements for developed water supplies are considered in this chapter. Results of studies conducted for the Putah Creek Cone Investigation are drawn upon heavily for estimates of present and ultimate water requirements. However, this bulletin stresses the economic factors involved in near future water development and the problems involved in securing appropriative water rights.

In the ensuing discussion, a clear distinction is made between water utilization and water requirements. The term "water utilization" as used in this bulletin, is defined as the consumption of applied water by vegetative growth in transpiration and building of plant tissue, and to water evaporated from adjacent soil. It does not include the consumptive use of precipitation. The term also refers to water consumed and evaporated by urban, recreational, and other non-vegetative types of use. The term is synonymous with "consumptive use of applied water".

The term "water requirement", as used in this bulletin, refers to the amount of water, exclusive of precipitation, needed to provide for all beneficial uses and for losses incidental to such uses. It is a measure of the amount of water required at a farmer's headgate in the case of agricultural use of water and the delivery to a water supply system to a community, or its equivalent, in the case of urban or recreational use.

Present Water Utilization

At the present time, development of water resources in the Upper Putah Creek Basin is almost entirely on an individual basis. There are no public or private agencies of any appreciable size providing water service. Because records of water use are not available, water utilization, in this bulletin, is evaluated using data on land use and population, together with estimated unit values of water use. In the near future, a more accurate evaluation may be possible as a result of data currently being collected by the department. The unit values of water use utilized in this report were taken from the "Report to the California State Legislature on Putah Creek Cone Investigation, December 1955" and results of similar studies of nearby areas.

The first survey of irrigated lands in the area was made in 1911, when it was reported that 142 acres in the Middletown area and 65 acres in Coyote Valley were under irrigation. Capell Valley was also canvassed at that time but it had no irrigated acreage. Apparently Pope Valley was not covered by the survey. From this beginning, irrigation increased slowly over the years until the past decade. It appears that from 1950 to 1960 the irrigated acreage more than doubled. This recent increase is due largely to development of ground water supplies in the Lake County portion of the basin and to construction of small surface reservoirs in the Napa County portion. One exception to this is the Bucksnort Creek area in Lake County which is served by Detert and McCreary Reservoirs, the largest surface storage reservoirs for local use in the upper basin.

Most of the newly irrigated lands have been planted to either mixed pasture grasses or alfalfa, although there is a large single acreage in Collayomi Valley that has been planted to a pear orchard and a number of smaller acreages planted to walnuts. Grain sorghums have been planted in several locations. Table 1 shows the present crop pattern. Plate 2, "Land Use and Classification" shows the location of these lands.

8. Dry-farmed orchard and vineyard lands along the southwesterly edge of Pope Valley.

9. Aerial view of a young orchard along Putah Creek illustrates full development of an irrigable area in Collayomi Valley.

TABLE 1

PRESENT (1960) LAND USE IN COUNTIES AND SELECTED AREAS OF THE UPPER PUTAH CREEK BASIN[a]

(In acres)

Class and type of land use	Lake County					Napa County					Upper Putah Creek Basin total
	Collayomi-Long Valleys area	Coyote Valley area	Bucksnort Creek area	Remainder of County	Lake County total	Pope Valley: Pope Creek area	Pope Valley: Burton-Hardin Creeks area	Capell Valley area	Remainder of County	Napa County total	
Urban and Recreational Lands											
Residential and commercial lands	180	0	0	10	190	10	10	10	20	50	240
Recreational lands	10	b/	0	310	320	70	0	50	310	430	750
Subtotals	190	b/	0	320	510	80	10	60	330	480	990
Irrigated Agricultural Lands											
Alfalfa	0	90	50	20	160	40	10	b/	90	140	300
Mixed pasture	430	340	620	90	1,480	100	90	130	50	370	1,850
Pasture and orchard	40	0	0	b/	40	0	0	0	0	0	40
Deciduous orchard											
Pears	180	0	0	0	180	0	0	0	10	10	190
Walnuts	40	10	0	b/	50	40	0	0	0	40	90
Field crops	b/	0	30	0	30	0	100	0	0	100	130
Subtotals	690	440	700	110	1,940	180	200	130	150	660	2,600
Total area requiring water service	880	440	700	430	2,450	260	210	190	480	1,140	3,590
Non Irrigated Agricultural Lands[d]											
Grain and hay	570	1,100	250	170	2,090	770	1,050	110	600	2,530	4,620
Deciduous orchard	150	140	0	130	420	20	30	b/	10	60	480
Vineyard	80	0	0	0	80	30	40	0	0	70	150
Alfalfa	0	0	0	0	0	0	80	0	0	80	80
Fallow and idle lands	30	0	0	b/	30	10	0	20	90	120	150
Subtotals	830	1,240	250	300	2,620	830	1,200	130	700	2,860	5,480
Native Vegetation											
Tree, brush, grass, and barren lands	5,530	2,880	1,250	122,870	132,530	7,130	3,980	780	222,350[c]	234,240	366,770
Total area not requiring water service	6,360	4,120	1,500	123,170	135,150	7,960	5,180	910	223,050	237,100	372,250
TOTAL AREA -- ALL LANDS	7,240	4,560	2,200	123,600	137,600	8,220	5,390	1,100	223,530	238,240	375,840

a/ Preliminary results of survey conducted for the current Inventory of Water Resources (Regan) Investigation. (Subject to revision.)
b/ Negligible.
c/ Includes about 19,300 acres inundated by Lake Berryessa.
d/ Does not include dry range.

Present Population

At present, the basin is sparsely populated with only about 1,200 year-round residents. About one-third of this population resides in Middletown, the largest urban community. The general areal distribution of the present population in the basin is shown in Table 2.

TABLE 2

ESTIMATED PRESENT (1960) POPULATION
IN UPPER PUTAH CREEK BASIN

County and area	Estimated present (1960) year-round population
Lake County	
Middletown	450
Mountain recreation areas	180
Remainder of county	290
Subtotal	920
Napa County	
Pope Valley	140
Capell Valley	90
Remainder of county	70
Subtotal	300
Total population	1,220

Present Consumptive Use and Water Requirements

Present water requirements for the lands shown in Table 1 are estimated to be about 8,500 acre-feet per year. Over 95 percent of this amount is required for irrigated agriculture. Only about 5,900 acre-feet of the estimated 8,500 acre-foot requirement are consumptively used. The remaining 2,600 acre-feet appear as return flow and are available for re-use. These estimates are based on the unit values of consumptive use of applied water shown in Table 3.

TABLE 3

ESTIMATED UNIT VALUES OF CONSUMPTIVE USE OF APPLIED WATER IN UPPER PUTAH CREEK BASIN

(Acre-feet per acre)

Class and type of land use	Estimated average annual consumptive use of applied water
Urban and Recreational Lands	
Residential, commercial, and rural	0.30
Recreational	0.15[a]
Irrigated Agricultural Lands	
Alfalfa	2.1
Mixed pasture	2.3
Pasture and Orchard	2.3
Deciduous Orchard	2.2
Field Crops	1.4
Vineyard	1.1

a/ Applied to all recreational lands except sparsely populated lands surrounding Lake Berryessa where a value 0.01 acre-feet per acre was used.

Water utilization appears to have increased during recent years. Table 4 shows the estimated change in consumptive use of applied water during the 6-year period 1954-1960. The estimated average increase in water utilization during that period was about 6.0 percent per year.

TABLE 4

ESTIMATED AVERAGE ANNUAL CONSUMPTIVE USE OF APPLIED WATER IN UPPER PUTAH CREEK BASIN

Class of land use by counties	Estimated consumptive use of applied water		
	1954[a]	1960	Change during 6-year period
Urban and Recreational Lands			
Lake County	b/	100	c/
Napa County	b/	40	c/
Subtotals	b/	140	c/
Irrigated Agricultural Lands			
Lake County	3,700	4,400	+ 700
Napa County	500	1,400	+ 900
Subtotals	4,200	5,800	+ 1,600
Total change			+ 1,600

a/ Taken from "Report to the California State Legislature on Putah Creek Cone Investigation, December 1955".
b/ Not computed.
c/ Changes assumed to be negligible.

Estimates of present water requirements were obtained by multiplying acreage of the various classes and types of land use, shown in Table 1, by the appropriate unit value of consumptive use of applied water, then dividing by the average application efficiency. For urban and recreational lands, efficiency of application was assumed to be 50 percent. For irrigated agricultural lands, efficiency was assumed to be 70 percent. Table 5 shows the result of this computation. Other uses of water, such as reservoir evaporation and consumptive use from direct precipitation, are not included in these totals. Although estimates of urban and recreational requirements were computed on the basis of land devoted to those purposes, a check on the basis of population, using 200 gallons per capita per day, was made with virtually the same results.

TABLE 5

RECONNAISSANCE ESTIMATE OF
PRESENT (1960) WATER REQUIREMENTS
IN UPPER PUTAH CREEK BASIN

(In acre-feet)

County and area	Estimated present average annual water requirement: Urban and recreational lands	Irrigated agricultural lands	Total
Lake County			
Collayomi-Long Valleys area	110	2,230	2,340
Coyote Valley area	a/	1,420	1,420
Bucksnort Creek area	a/	2,250	2,250
Remainder of Lake County	100	360	460
Lake County totals	210	6,260	6,470
Napa County			
Pope Valley area			
Pope Creek area	20	570	590
Burton-Hardin Creeks area	10	530	540
Capell Valley area	20	430	450
Remainder of Napa County	20	460	480
Napa County totals	70	1,990	2,060
PUTAH CREEK BASIN TOTALS	280	8,250	8,530

a/ Negligible.

Although it is known that the basin experiences deficiencies in natural surface water supply during fall and summer months, the magnitude and extent of these deficiencies are not known. However, in the near future, it may be possible to determine this deficiency from data being collected for the current Inventory of Water Resources and Requirement Investigation.

Future Water Requirements

As previously stated, over 95 percent of the present water requirements in the Upper Putah Creek Basin is for irrigation of agricultural lands. Although urban and recreational demands for water are expected to increase in the future, it is anticipated that irrigation will continue to be the primary water requirement.

The future amount of water that will be developed for use in the basin will largely depend upon the capabilities of the land under irrigation to produce climatically adapted crops, together with the cost of developing water supplies in comparison to the net returns to be derived. For surface water development, the ability to secure appropriate water rights may become a controlling factor. Ultimately full utilization of land resources within economic limits will define the maximum potential water requirement.

Land Classification Survey

The capabilities of the land to support irrigated agriculture in the Upper Putah Creek Basin were studied in 1954 as a part of the Putah Creek Cone Investigation. Land was classified according to its irrigability and crop adaptability. The land classification procedures employed an examination of the soil characteristics and the physiography of the landscape.

Field mapping was done on aerial photographs having a scale of 1:20,000. Soil borings, land form characteristics, existing vegetative cover, and published soil survey maps were used to determine the crop adaptability, suitability, and limitations of each parcel of land delineated on the aerial photographs.

Acreage determinations were made by transferring the field data from the photos to base maps, where they could be accurately measured. About 28,000 acres were found to suitable for irrigation during that survey.

An examination of results of similar surveys conducted in 1947 for the State Water Resources Board, published in Bulletin No. 2, indicated that there is an additional 640 acres of irrigable land in the vicinity of Eticuera Creek. These acres were omitted in the 1954 survey because of their close proximity to the then proposed Lake Berryessa, but have been included in this investigation.

Further field examination during this investigation revealed that in some localities certain soil characteristics which materially affect crop adaptability had not been delineated in previous surveys. These were, however, delineated during this investigation. The revised classification and acreages, by selected areas, is shown in Table 6. To facilitate a study of potential service areas and aid in analysis of local water development projects these tabulations were made in more detail than in previous bulletins. The revised tabulations show about 2,800 acres of Vh lands which were formerly classified as "V-lands". Because of the reconnaissance nature of this bulletin, and so as not to duplicate the detailed re-evaluation of land classification presently being conducted as part of the current Inventory of Water Resources and Requirements Investigation, the land classification shown on Plate 2 is as mapped for previous investigations. However, full consideration is given to these changes in land classification in all pertinent sections of this bulletin. Classification symbols used in Table 6 are as follows:

Land Classification Standards

Irrigable agricultural lands have been classified, in accordance with their topographic characteristics, as V, H, or M lands.

V - These lands are level or slightly sloping and vary from smooth to hummocky or gently undulating relief. The maximum allowable slope is 6 percent for smooth, reasonably large-sized bodies lying in the same plane. As the relief increases and becomes more complex, lesser slopes are allowed. These lands are suitable for all climatically adapted crops.

H - These are lands with greater slope and/or relief than those of the V class. They vary from smooth to moderately rolling or undulating relief. The maximum allowable slope is 20 percent for smooth, reasonably large-sized bodies lying in the same plane. As the relief increases and becomes more complex, lesser slopes are allowed.

M - These are lands with greater slope and/or relief than those of the H class. They vary from smooth to steeply rolling or undulating relief. The maximum allowable slope is 30 percent for smooth, reasonably large-sized bodies lying in the same plane. As the relief increases and becomes more complex, lesser slopes are allowed.

Lands identified as V, H, or M have permeable soils with medium to deep effective root zones. They are free of rock and not limited by a high water table. Variations from this pattern are indicated by the following subsymbols.

r - Indicates the presence of rock on the surface or within the plow zone in sufficient quantity to prevent use of the land for cultivated crops.

p - Indicates shallow depth of the effective root zone, which limits use of these lands to shallow-rooted crops.

h - Indicates very heavy textures, which make these lands best suited for production of shallow-rooted crops.

Miscellaneous Classes

N   Includes all lands which fail to meet the requirements of the above classes.

10. Newly constructed farm ponds in Pope Valley. Numerous small reservoirs such as these furnish a limited water supply for stockwatering and domestic purposes.

11. Irrigable land in Pope Valley. A substantial augmentation of the present limited water supply is required here for development of irrigated agriculture.

TABLE 6

CLASSIFICATION OF IRRIGABLE LANDS IN COUNTIES
AND SELECTED AREAS OF THE UPPER PUTAH CREEK BASIN a/

(In acres)

Land class	Lake County					Pope Valley		Napa County			
	Collayomi-Long Valleys area	Coyote Valley area	Bucksnort Creek area	Remainder of county	Lake County total	Pope Creek area	Burton-Hardin Creeks area	Capell Valley area	Remainder of county b/	Napa County total	Upper Putah Creek Basin total
Valley Lands											
V	2,310	2,050	450	740	5,550	390	1,980	350	510	3,230	8,780
Vr	--	--	--	20	20	--	20	--	--	20	40
Vp	710	--	--	70	780	260	40	--	30	330	1,110
Vh	720	920	660	--	2,300	300	160	--	--	460	2,760
Vpr	--	--	10	10	20	30	--	--	--	30	50
Subtotals	3,740	2,970	1,120	840	8,670	980	2,200	350	540	4,070	12,740
Hilly Lands											
H	1,610	390	180	2,270	4,450	3,250	940	500	1,760	6,450	10,900
Hr	--	--	--	30	30	40	--	--	--	40	70
Hp	180	60	80	280	600	210	450	--	340	1,000	1,600
Hpr	--	--	10	100	110	--	--	--	--	--	110
M	350	--	--	360	710	180	30	10	490	710	1,420
Mp	--	--	--	130	130	900	630	--	140	1,670	1,800
Subtotals	2,140	450	270	3,170	6,030	4,580	2,050	510	2,730	9,870	15,900
Total irrigable area	5,880	3,420	1,390	4,010	14,700	5,560	4,250	860	3,270	13,940	28,640
N	1,360	1,140	810	119,590	122,900	2,660	1,140	240	220,260 c/	224,300	347,200
TOTAL AREA	7,240	4,560	2,200	123,600	137,600	8,220	5,390	1,100	223,530	238,240	375,840

a/ Except for revisions discussed in text, this tabulation is based on survey conducted for the Putah Creek Cone Investigation and includes irrigable lands presently devoted to irrigation, urban, and recreational development.

b/ Includes about 640 acres of irrigable land in the vicinity of Eticuera Creek that was mapped for State Water Resources Board Bulletin No. 2 but which was not included in the survey for the Putah Creek Cone Investigation.

c/ Includes about 19,300 acres of land inundated by Lake Berryessa.

Water Utilization Under Ultimate Conditions of Development

In addition to the land classification studies conducted for the Putah Creek Cone Investigation, considerable emphasis was placed on the projection of future crop patterns and water requirements under "ultimate conditions" of development. Ultimate conditions were assumed to occur after an unspecified but long period of time, when land use and water supply development would be at a maximum and essentially stabilized. First, the net area that might be irrigated in any one season was estimated by reducing gross irrigable acreages determined in the land classification survey by appropriate factors. The numerical value of the applied factors depended on the size, shape, and location of the lands; inclusions of small nonirrigable areas within irrigable lands; productive capacity of the lands; ease of irrigating fields; and areas to be utilized by roads, highways, canals, farmsteads, and other nonagricultural land uses. Economic conditions were not considered as a limiting factor under the concept of ultimate development.

Second, an assumed cropping pattern was projected onto the net irrigable area based on land capability, irrigated crops grown at that time, local climatic conditions, and possible future development.

Finally, appropriate unit values of consumptive use of applied water (listed in Table 3) were used to estimate possible ultimate water utilization. It was estimated that of the 28,000 acres of irrigable land, about 22,000 acres would ultimately be productive and that they would consumptively use an average of about 37,800 acre-feet of water per year over and above that supplied by rainfall. The results of these land use and water utilization forecasts, taken from the Putah Creek Cone Investigation, are summarized in Table 7.

TABLE 7

ESTIMATED ULTIMATE PATTERN OF LAND USE
AND WATER UTILIZATION ON IRRIGABLE LANDS
IN UPPER PUTAH CREEK BASIN

Item	Lake County	Napa County	Total Upper Putah Creek Basin
Land Use, in Acres			
Irrigated Crops			
Alfalfa	1,600	1,000	2,600
Pasture	4,110	3,530	7,640
Orchard	1,900	1,150	3,050
Hay and grain	1,800	2,000	3,800
Field	1,400	1,410	2,810
Truck	1,200	820	2,020
Subtotal	12,010	9,910	21,920
Nonirrigated area	2,540	3,380	5,920
Urban area[a]	150	10	160
Total	14,700	13,300	28,000
Average Annual Water Utilization, in Acre-Feet			
Consumptive Use of Applied Water	21,300	16,500	37,800

a/ Does not include urban areas overlying nonirrigable lands.

It was realized that such long-range forecasts would be subject to large errors in detail and appreciable error in the aggregate. However, these forecasts, which were based upon the best available data at the time of formulation, are of considerable value in establishing long-range plans for water resources development. They were the basis for establishing a water right reservation, with certain limitations, for future appropriations of water for beneficial use in the upper basin above Monticello Reservoir. The water right reservation of 33,000 acre-feet per year was based on the maximum future impairment to runoff above Monticello Reservoir which was assumed to be the difference between consumptive use under ultimate conditions of development and consumptive use during 1954.

Some Economic Aspects of Water Development

The value of water lies in its use. It is believed that within the foreseeable future the major need for water will be for irrigated agriculture. Emphasis is given herein to estimates of gross farm income from crops adapted to the basin under both irrigated and dry-farmed conditions; to estimates of farm production costs for the various irrigated and dry-farmed crops, exclusive of the cost of water; to payment capacity for water for the various crops; and to net farm income for the various irrigated and dry-farmed crops. Although preliminary, these data provide a basis for determining what crops can be economically grown under irrigation and give an indication of the maximum amount a farmer could afford to pay for water.

In addition to climatic and soil considerations, selection of representative crops is contingent upon comparative economic advantage. The transportation of agricultural commodities, in most instances, is dependent upon trucking over a single state or county road from each of the potential service areas into or through Napa Valley. Therefore, the selection of representative crops for the area was limited to those which could be easily transported to outside markets and/or those which demonstrated an economic advantage, or least disadvantage, with respect to other competitive areas of production. For this study, pears, walnuts, wine grapes, alfalfa hay, and irrigated pasture were used as representative crops in establishing repayment ability of irrigated crops in the potential service areas of the basin.

Farm budget analyses were developed for the foregoing representative crops. Anticipated crop yields and prices were based on information supplied by local agricultural commissions, farm advisors, and previously developed data for nearby areas. Generally they represent an average of the 5-year period 1952-1956. The use of this base period has been adopted as a departmental standard for agricultural studies as representative of the price-cost relationship that could be expected to prevail during a long-term project repayment period.

The term "payment capacity" refers to the maximum amount that an average farmer, operating an economic farm unit, can afford to pay for water for the particular crop being considered. Payment capacity is the difference between gross farm income and the total cost of production, excluding water costs, but including labor and management costs and an equitable return on the required capital investment. Payment capacity does not necessarily infer that a farmer is willing to pay that amount for irrigation water.

Average annual payment capacities derived from the farm budget analyses ranged from a low of about $11 per acre for irrigated pasture to a high of about $69 per acre for pears. By applying the unit values of water use (listed in Table 3) with an irrigation efficiency of 70 percent, average annual payment capacities were estimated to range from a low of about $3 per acre-foot for irrigated pasture to a high of about $33 per acre-foot for wine grapes. Payment capacity for pears and other deciduous orchard crops would average about $20 per acre-foot. To illustrate the advantage of raising irrigated crops in preference to dry-farmed crops and to show the complete array of payment capacities for selected representative crops, a summary of the average annual crop budget analysis and payment capacities are presented in Table 8. Examination of the difference between net income from irrigated and dry-farmed crops indicates clearly the greater net income which can be obtained from irrigation in place of dry-farming. But, in view of the relatively low payment capacity for irrigated pasture ($3 per acre-foot) and alfalfa ($6 per acre-foot) in relation to the expected cost of surface water development, it is doubtful if the acreage of these crops will expand significantly in the foreseeable future. However, vineyard and deciduous orchard crops have payment capacities in excess of the expected cost of surface water development at several localities of the basin. It is possible that truck crops may be grown in the future, but these do not appear to have the relative economic advantage offered by vineyard and orchard crops.

SUMMARY OF RECONNAISSANCE ESTIMATES OF
FARM BUDGET ANALYSIS AND PAYMENT CAPACITY
OF SELECTED REPRESENTATIVE CROPS
IN UPPER PUTAH CREEK BASIN

(Dollars per acre)

Crops	Gross income	Specified production costs a/	Net farm income before water charges	Payment capacity for water	Net farm income assuming water costs equal to payment capacity b/
Pears					
Irrigated	750	528	222	69	153
Dry-farmed	420	346	74	--	74
Difference	330	182	148	69	79
Walnuts					
Irrigated	338	194	144	56	88
Dry-farmed	180	131	49	--	49
Difference	158	63	95	56	39
Grapes					
Irrigated	300	179	121	53	68
Dry-farmed	142	98	44	--	44
Difference	158	81	77	53	24
Pasture					
Irrigated	108	64	44	11	33
Dry-farmed	40	28	12	--	12
Difference	68	36	32	11	21
Alfalfa Hay c/					
Irrigated	130	70	60	17	43

a/ Includes all costs except charges for operators labor, return on operators investment, return on operators management of enterprise, & cost of water in the case of irrigated land.
b/ Includes allowance for operators labor, management, and interest on investment.
c/ A farm-investment-budget analysis was not computed for dry-farmed alfalfa.

Possible Service Areas for Water Development

For reconnaissance planning purposes the individual valley areas in the Upper Putah Creek Basin can serve as water service areas. Consideration was given to potential projects capable of serving the Collayomi-Long Valleys area, Coyote Valley, Bucksnort Creek area, Pope Valley, Capell Valley, and the urban-recreational type lands along the westerly shore of Lake Berryessa. Pope Valley was considered in two parts, the Pope Creek sub-area, and the Burton-Hardin Creeks sub-area. With the exception of recreational lands surrounding Lake Berryessa, potential projects for the remaining scattered and isolated parcels of irrigable land were not considered. However, it may be possible to develop small projects capable of serving these lands. It was assumed that such development would be the result of individual efforts rather than of group or community development. These excluded irrigable lands comprise about 25 percent of the total gross irrigable area in the basin.

Potential Future Water Requirements in Selected Service Areas

In this section, the effect of current economic factors influencing future demands for water is stressed, rather than the previously discussed concept of ultimate conditions of development. The experience of several years, together with additional information on economic factors, indicates that the future pattern of land use may be significantly different than that envisioned for ultimate conditions of development in the report on the Putah Creek Cone Investigation. Nevertheless, demands for water will be largely dependent on land use.

Future Land Use. At present, there seems to be a general interest in development of fruit and vineyard acreage in various areas of northern California. This interest is being stimulated by a demand for acreage to replace lands going out of production, because of urban encroachment in and adjacent to Napa Valley and the San Francisco Bay Area. The wine industry in California is continually seeking lands such as those of the Upper Putah Creek Basin, which are suitable for the production of grapes high in acids. Areas of the State suitable for the production of high-acid wine grapes are critically limited by climate and soil characteristics.

At the present time, the commercial pear acreage in California is being jeopardized by pear decline disease. Little is known, as yet, about the range of the disease or the eventual impact it may have on the pear industry. The Upper Russian River area, free from this disease at this writing, is in many ways similar to the valleys of the Upper Putah Creek Basin. Other deciduous orchard crops, such as walnuts and prunes, are also adapted to the area.

In view of this unique crop adaptability coupled with the relatively low payment capacity of irrigated pasture and alfalfa, future irrigated agriculture, supplied from surface water developed by projects discussed in subsequent portions of this bulletin, probably will be restricted to deciduous orchard and vineyard crops.

In addition to agricultural land uses, future water requirements for domestic, commercial, and recreational purposes must also be considered. In cases where these types of development encroach on the irrigable lands in the basin, the requirement computed for irrigation of these lands should be more than ample for the anticipated needs for these purposes. Development of these types which occur on nonirrigable lands, such as that taking place along the westerly shore of Lake Berryessa, will have water requirements over and above those computed for the irrigable lands.

A thorough appraisal of future development and attendent water requirements for these types of development was not made during this investigation. However, in a recent report by the Napa County Planning Commission, it was estimated that there are about 5,300 acres along the westerly shore of Lake Berryessa and another 3,100 acres in Capell Valley which are suitable for residential development. It was estimated that these lands could ultimately support populations of about 29,100 and 33,600, respectively. Urban development of this magnitude in Capell Valley would eliminate the need for irrigation water in that valley.

The certainty of estimates tends to diminish as the time from which they are made lengthens. An estimate for a five year period may be expected to be fairly accurate. A projection of conditions 50 years from the date of the estimate has a probability of being much less accurate. However, since it is necessary to make economic analyses covering the entire economic life of a project, estimates as made as well as possible with the present limits of the data and knowledge available.

There is no present basis on which to estimate the length of time people will live or vacation at Lake Berryessa. It seems logical to suppose that large percentage of the residents of the area will be retired. Due to the year-round availability of recreation at the lake and its proximity to Sacramento and the San Francisco Bay area, it could have a great attraction to people as a second dwelling. For the most part, this type development would be used for weekend or short vacation stays, possibly on a year-round basis. As development proceeds in these areas, it may be possible to make a more accurate determination of the future. Data presently being collected as a part of the current Inventory of Water Resources and Requirements Investigation may assist in this regard.

A point not to be forgotten is the fact that Lake Berryessa (Monticello Reservoir) was primarily designed as a water conservation reservoir and, during a prolonged drought, is expected to have an extremely long carry-over period. During such a drought, the lake level would be lowered to meet the demands for water downstream. This lowering would cause the shore-line to recede (in some cases several miles) from the developable areas, thereby reducing the relative attractiveness of the area, and probably inhibiting growth. Even if the area were already developed to a high degree, weekend and vacation stays probably would be reduced during an extended drought.

The situation may be visualized by comparing the figures in Table 9 "Water Surface Area of Lake Berryessa at Selected Levels" with Figures I and II. Figure I shows the water levels as they would have existed from 1916 to 1950 if Monticello Dam had existed during those years. From 1916 to 1936 the water surface elevation and surface area

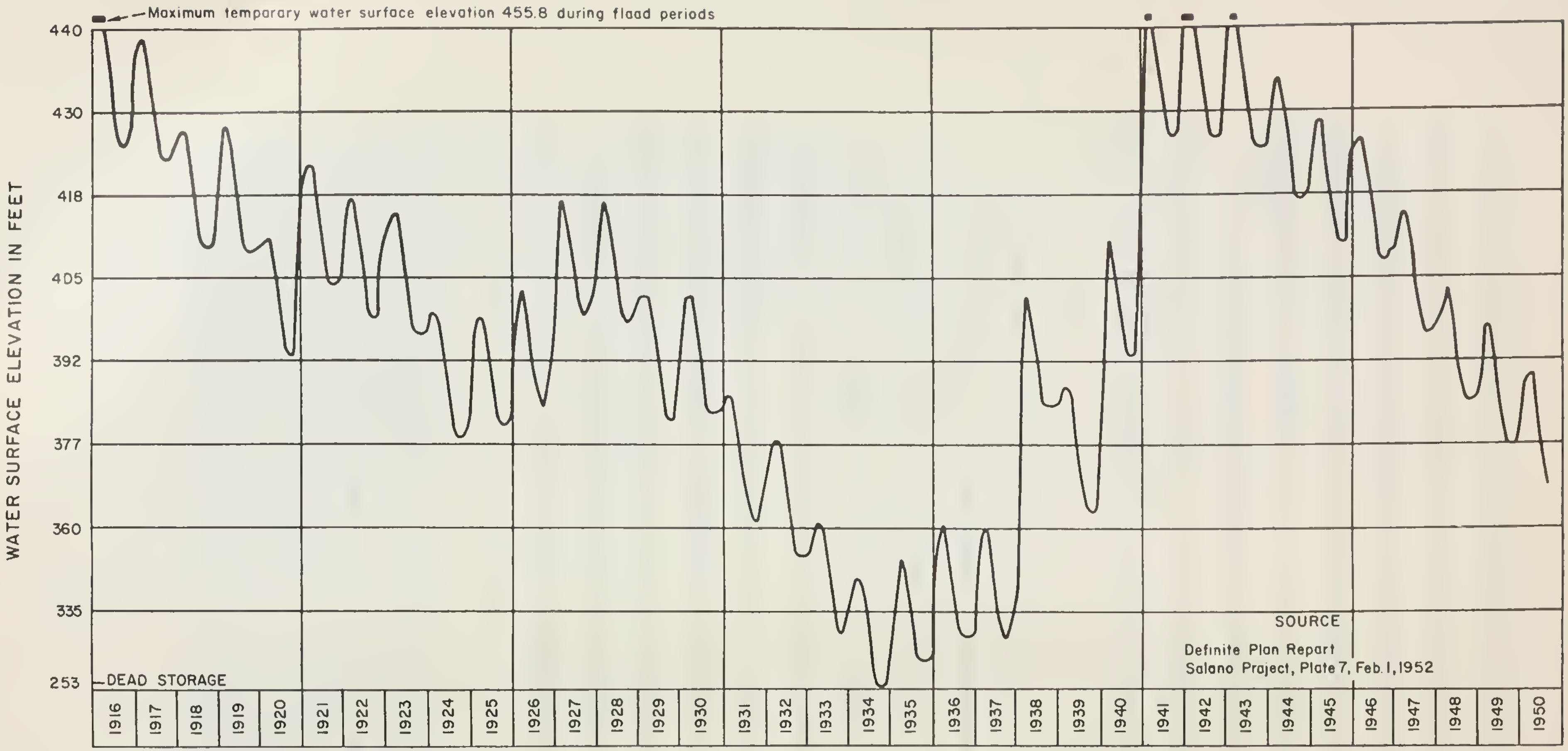


Fig. I – WATER SURFACE LEVELS,
LAKE BERRYESSA

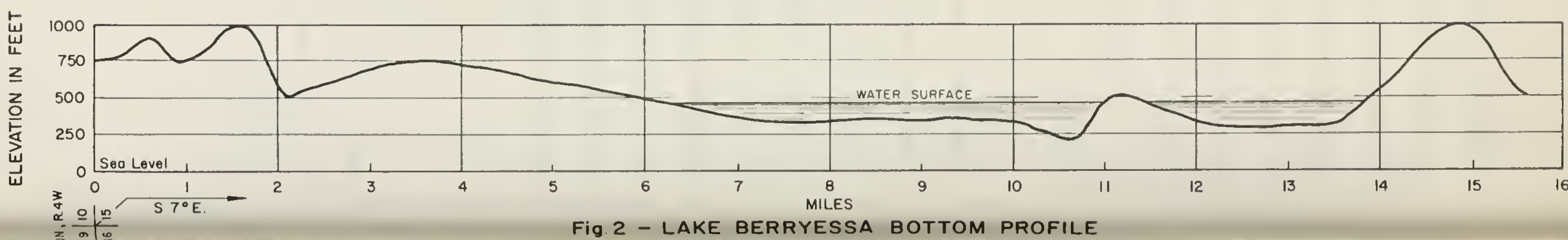


Fig. 2 – LAKE BERRYESSA BOTTOM PROFILE

TABLE 9

WATER SURFACE AREA OF LAKE BERRYESSA
AT SELECTED LEVELS

Water Level (height above mean sea level)	Water Surface (acres)	Water Level (height above mean sea level)	Water Surface (acres)
185	0		
190	1	340	7,172
200	14	350	8,799
210	50	360	10,190
220	113	370	11,472
230	185	380	12,634
240	266	390	13,923
250 1/	394	400	15,128
260	574	410	16,233
270	766	420	17,295
280	1,044	430	18,289
290	1,445	440 2/	19,290
300	2,131	450	20,213
310	2,980	460	21,103
320	4,168	470	21,909
330	5,438	480	22,682

1/ Dead storage elevation: 253 feet
2/ Spillway lip elevation: 440 feet

Source: U.S.B.R. Map No. G1664e, June 24, 1947 would have trended downward. The lake would not have filled until early 1941. Figure II, which shows a cross section along the longitudinal axis of Lake Berryessa, cannot be used to compute the horizontal water recession at any particular point on the lake during times of drought. The distance between any given point and the water's edge for each water surface elevation depends upon the contours of the land at that point.

Future Supplemental Water Requirements. Future average annual supplemental water requirements necessary to fully develop all presently undeveloped irrigable lands in the selected service areas are estimated to be about 30,000 acre-feet. However, because of the wide divergence in unit water requirements of vineyard and orchard crops, and the speculative nature of predicting relative amounts of each crop, this projection cannot be made with any degree of certainty. Consequently, projections of future supplemental agricultural water requirements were made on high, low, and intermediate bases.

It was considered very unlikely that all irrigable lands would be devoted exclusively to either vineyard or orchard crops. Hence, the estimated minimum supplemental requirement of about 26,000 acre-feet per year was based upon an assumed cropping pattern of 80 percent vineyard and 20 percent orchard. Similarly, the estimated maximum supplemental requirement of about 38,000 acre-feet per year was based on an assumed cropping pattern of 20 percent vineyard and 80 percent orchard. This procedure establishes the probable range of the average annual supplemental water requirement to fully develop all presently undeveloped irrigable lands in the selected service areas. The intermediate estimate, amounting to about 30,000 acre-feet per year, represents the most likely value, considering variations in soil characteristics and present trends in development.

The total average annual future water requirement for the selected service areas was estimated to be about 38,000 acre-feet by adding the present requirement to the estimated future supplemental requirement. A summary of the results of these estimates, by service areas, is presented in Table 10.

However, if either Goodings and/or Walter Springs Reservoirs were constructed as a means of developing additional water supplies for the Pope Valley Service Area, the indicated values of net irrigable area and water requirements would be further reduced, by inundation of a portion of the irrigable lands. A review of data on file with the Water Rights Board indicates that development of additional supplies in the Bucksnort Creek area has taken place since the survey of present land use. This development probably would result in a higher present water use and requirement and correspondingly lower supplemental water requirements than shown in the table. The extent of the inundation of irrigable area and water requirements in Pope Valley and the recent development in the Bucksnort Creek area are discussed in more detail in subsequent portions of the bulletin.

Table 10 does not contain an estimate of future water requirements in the vicinity of Lake Berryessa. The difficulties and uncertainties in making such an estimate have already been discussed. The Napa County Planning Commission estimated that if full, residential development of these lands were to take place, they would have an average annual water requirement exceeding 10,000 acre-feet. Over one half of this amount would be required in the Capell Valley area. Recently, in behalf of Napa County, the Bureau of Reclamation filed water right application No. 19934 in the amount of 7,500 acre-feet per year to meet these possible future needs along the shore of the lake and in Capell Valley. In a supplement to the application, it was estimated that such an amount could be required for these purposes, within the next 25 years. Of the 7,500 acre-feet, about 4,000 acre-feet would be required in Capell Valley and 3,500 acre-feet would be required along the shore of the lake. It was considered likely that the demands for water along the westerly shore of the lake will increase and that they probably will reach at least 1,000 acre-feet per annum within the next 50 to 60 years.

TABLE 10

RECONNAISSANCE ESTIMATES OF FUTURE
AGRICULTURAL WATER REQUIREMENTS IN SELECTED
SERVICE AREAS OF THE UPPER PUTAH CREEK BASIN

County and selected service area	Gross irrigable area, in acres	Net irrigable area, in acres a/	Present irrigated area, in acres	Net irrigable area remaining to be developed, in acres	Estimated future supplemental agricultural water requirement for development of remaining irrigable lands, in acre-feet per year: Minimum conditions	Maximum conditions	Intermediate conditions b/	Estimated present water requirement, in acre-feet per year	Estimated total future water requirement, in acre-feet per year
Lake County									
Collayomi-Long Valley	5,880	4,700	690	4,010	7,600	11,200	8,700	2,300	11,000
Coyote Valley	3,420	2,340	440	1,900	3,600	5,300	4,000	1,400	5,400
Bucksnort Creek area	1,390	1,170	700	470	900	1,300	1,100	2,300	3,400
Subtotals	10,690	8,210	1,830	6,380	12,100	17,800	13,800	6,000	19,800
Napa County									
Pope Valley									
Pope Creek area c/	5,560	3,940	180	3,760	7,100	10,500	7,700	600	8,300
Burton-Hardin Creeks area c/	4,250	3,100	200	2,900	5,500	8,100	7,800	500	8,300
Capell Valley	860	690	130	560	1,100	1,600	1,200	500	1,700
Subtotals	10,670	7,730	510	7,220	13,700	20,200	16,700	1,600	18,300
SELECTED SERVICE AREA TOTALS	21,360	15,940	2,340	13,600	25,800	38,000	30,500	7,600	38,100

a/ Estimated portion of gross irrigable area that would be irrigated in any one season by allowing for such factors as size, shape, and ease of development, rights of way, inclusions of nonirrigable area, and productive capacity.

b/ Adopted value. Represents most probable value based on present knowledge of variations of soil characteristics and present trends of development.

c/ Values of net irrigable area and future water requirements would be further reduced, by inundation, upon the construction of Goodings and/or Walter Springs Reservoirs.

Effect of Water Rights on Upper Basin Development

The value of water lies in its use. Water rights, as used herein, are essentially rights to the use of water and are so recognized by law. Consequently, the law concerning water relates principally to the rights and duties in its use. An important prerequisite to a water development project is the acquisition of the necessary rights to divert, store, and use the quantities of water required for the operation of that project.

Nature of Water Rights

Only a small portion of California water law has been established by legislative enactment, the major portion having been established by court decisions over a period of about one hundred years. In general, water rights in California are derived from three separate doctrines; the riparian doctrine, the doctrine of appropriation, and the doctrine of correlative rights. In many cases, these doctrines are to some extent conflicting, and water rights based thereon have been modified by court action.

Riparian Rights. Riparian rights apply to surface waters and to underground waters flowing in known and definite channels. In most cases, they are paramount to appropriative rights. They are not defined in any California statute but are a modification of the common law doctrine of riparian rights. They have been established and upheld in California by decisions of the courts and confirmed by the provisions of Section 3, Article XIV of the State Constitution.

A riparian right exists by reason of ownership of land abutting upon a natural stream or body of water. A parcel of land loses its riparian right when it is severed from land bordering the stream unless the right is reserved for the severed parcel. A riparian right may also be lost when transferred apart from the land by grant, contract, or condemnation. Once lost, the riparian right can never be restored. A riparian right cannot be transferred for use upon another parcel of land.

Although now subject to reasonable beneficial use, a riparian right is neither created by use nor lost by nonuse. Priority of use does not establish priority of right, that is, one cannot claim a superior riparian right merely because he used the water first. If there is insufficient water for the reasonable requirements of all riparian owners, they must share the available supply.

Water cannot be stored or withheld for prolonged periods of time to provide for a deferred use under claim of a riparian right. Furthermore, a riparian right does not apply to foreign water. That is, water brought from a different watershed cannot be used under claims of riparian right.

Although riparian rights are known to exist in the Upper Putah Creek Basin, a determination of these rights was not made during this investigation nor in any known previous investigation.

Appropriative Rights. Appropriative rights apply to surface and to underground waters flowing in known and definite channels, and are based on the principle that first in time is first in right.

If there is insufficient water to meet the needs of all appropriators, the first appropriator has exclusive right to use the water to the extent of his appropriation. Each later appropriator has a like priority with respect to other appropriators junior in time.

Appropriated water may be used on or in conjunction with lands away from streams, as well as lands continguous to streams. Under an appropriative right, water may be stored during periods of high flow for subsequent use during periods of low flow. As contrasted to riparian rights, appropriative rights are established by beneficial use and may be lost by nonuse.

Prior to the Water Commission Act of 1914 (California Statutes 1913, Chapter 586, page 1012), appropriative rights could be acquired by simply taking and applying water to beneficial use. The priority of a right initiated prior to 1872 related back to the date of the first substantial act toward putting water to beneficial use, provided the diversion and beneficial use of waters were completed with reasonable diligence. In 1872, a permissive procedure for perfecting an appropriation of water was established by the addition of Sections 1410 through 1422 of the Civil Code. Under these sections, provision was made for posting a notice of appropriation at the proposed point of diversion and recording a copy thereof with the County Recorder. If this statutory procedure was followed and the appropriation was completed with due diligence, priority of the right dated back to the date of posting the notice of appropriation. After 1872 the priority of an appropriator who did not comply with the Civil Code procedure was established when water was first applied to beneficial use.

In order to now successfully assert an appropriative right which was initiated prior to December 19, 1914, where the validity of such right is in dispute, evidence is required of both the original appropriation and of subsequent maintenance of the right by continuous and diligent application of the water to beneficial use.

The two methods of appropriation existing prior to the effective date of the Water Commission Act are no longer available. In order to now initiate an appropriative right an application must be filed with the State Water Rights Board in compliance with the provisions of Part 2, Division 2 of the Water Code.

Neither the filing of an application nor its approval by the board will establish a valid water right. An appropriative right is created by applying the water sought to beneficial use in accordance with law and the terms and conditions of the permit that may be issued pursuant to the application. The purpose of filing a water right application is to initiate a right to use unappropriated water and to establish a record of such right so that its status in relation to other rights may be definitely determined.

A tabulation of active applications to appropriate water in the Upper Putah Creek Basin above Monticello Reservoir, initiated since 1914, now on file with the State Water Rights Board, is presented in Appendix A of this bulletin. This tabulation is complete as of September 1961. It supersedes a similar tabulation shown in Appendix B of the report on the Putah Creek Cone Investigation, dated December 1955.

Correlative Rights to Underground Water. From a legal standpoint, there are two classes of underground waters; namely, subterranean streams flowing through known and definite channels, and percolating waters. Waters in the first class are regarded as identical to waters occurring in surface streams and are subject to both the riparian and appropriative doctrines. To meet this first classification, a definite underground stream must have characteristics similar to a surface water course such as a channel with well defined limits, a source of supply, a measurable flow in a specific direction, and a substantial existence.

Percolating water is said to be all ground water not included in the first class and is not subject to appropriation under Part 2, Division 2 of the Water Code. So far as is presently known, most extractable ground water in Upper Putah Creek Basin would fall into this latter class. Rights to percolating waters are subject to the doctrine of correlative rights. Under this doctrine, overlying land owners have equal rights to the common ground water supply for beneficial use on lands overlying the common supply. The vested rights of the owners to develop ground water for use on overlying lands are, in general, paramount to rights obtained under the appropriative doctrine. Overlying rights to ground water are appurtenant to the land and vested in the owner by reason of his ownership of the land. The right of each owner is equal and correlative to the rights of all other overlying owners. In these respects, rights to use of ground water are similar to riparian rights pertaining to surface waters.

Water Right Applications at Monticello Reservoir

In furtherance of the Solano County Project, the Bureau of Reclamation has filed water rights applications proposing appropriations from Putah Creek at the Monticello site. Data pertinent to these applications are shown in the following tabulation:

Application No.	Date filed	Amount of Permit: second feet	Amount of Permit: acre-feet per year	Purpose of use[a/]	Status
11199	10-29-45	- -	1,000,000	D-M-In-I-R	Permit
12578	6-30-48	900	600,000	I-D	Permit
12716	9-27-48	116	320,000	M-In-D-R	Permit
19356	4-15-60	1,250	1,600,000	P	Pending
19934	1-27-61	20	7,500	M-D	Pending

a/ D-Domestic, I-Irrigation, M-Municipal, In-Industrial, P-Power, R-Recreational

Water sought under Application No. 19934 will be used for municipal and incidental uses within 10,000 net acres within 40,100 gross acres bordering Lake Berryessa in Napa County. Water sought under Application No. 19356 will be used for the generation of hydroelectric power at Monticello Dam. Protests have been received against both applications. It appears necessary for the State Water Rights Board to hold a hearing on Application 19356 before further action can be taken with respect to it. A decision following a hearing is pending with respect to Application No. 19934.

Water sought under Application Nos. 11199, 12578, and 12716 is sought for use within a 440,000 acre body of land which covers all of the valley lands in Solano County, a small adjacent area in Napa

County, the City of Crockett in Contra Costa County, and the Davis Campus of the University of California in Yolo County.

On February 7, 1957, the State Water Rights Board issued Decision No. 869 in which it ordered Applications Nos. 11199, 12578, and 12716 be approved subject to certain terms and conditions. Item 5 pertaining to the amount of water to be appropriated by storage and Item 14 pertaining to stream flow depletion above Monticello Dam read as follows:

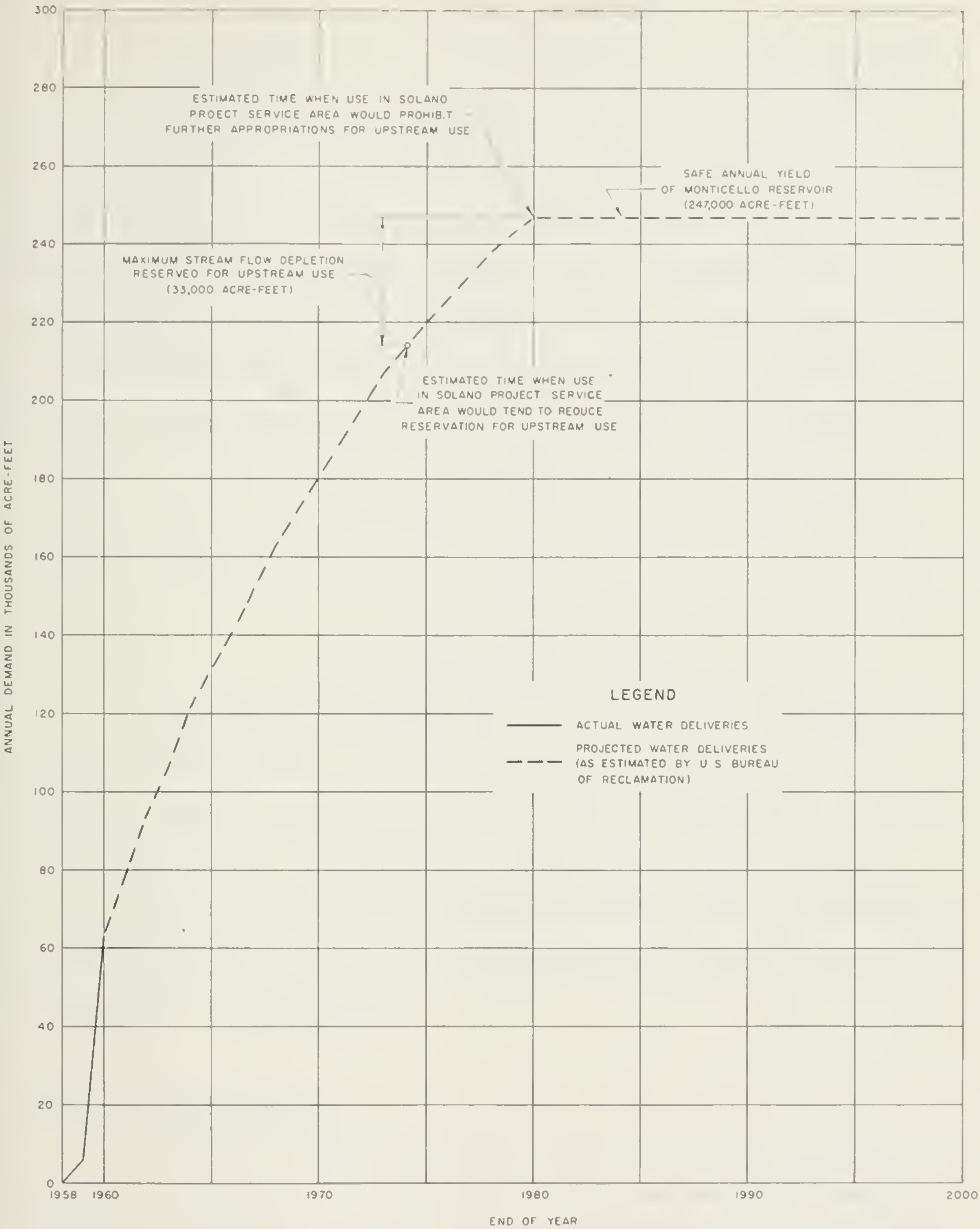
> "5. The total amount of water to be appropriated by storage for all purposes under permits issued pursuant to Applications 11199, 12578 and 12716 shall not exceed 1,600,000 acre-feet between November 1 of each year and May 31 of the succeeding year.
>
> "14. The permits and all rights acquired or to be acquired thereunder are and shall remain subject to depletion of stream flow above Monticello Reservoir not to exceed 33,000 acre-feet of water annually, by future appropriations of water for reasonable beneficial use within the watershed of Putah Creek above said reservoir; provided such future appropriations shall be initiated and consummated pursuant to law prior to full beneficial use of water within the project service area under these permits."

The reservation of water for use above Monticello Dam contained in permits issued pursuant to Applications Nos. 11199, 12578, and 12716, applies to water subject to future appropriation (appropriation after February 7, 1957) under State laws. It appears, therefore, that in the Upper Putah Creek Basin this reservation does not apply to riparian lands or to ground water being applied to beneficial use on overlying lands, or to the refilling of these ground water basins by natural percolation. The limitations would apply to ground water tributary to Putah Creek, extracted for use on land not overlying the ground water basin and to the refilling of ground water basins not tributary to Putah Creek with tributary water by artificial means.

The State Water Rights Board has retained jurisdiction over the permits issued to the United States for a period up to 15 years and shall prior to the end of this period, hear, review, and make further orders as may be required concerning project water released for downstream use.

Recent estimates of the Bureau of Reclamation indicate that the entire safe annual yield from Monticello Reservoir may be put to beneficial use by as early as 1980, and that all but 33,000 acre-feet of this yield may be put to use by 1974. The estimated build-up of demand for water in the Solano Project Service area is depicted graphically in Figure 3. Assuming that the bureau's estimate accurately defines the development rate in the Solano Project Service area, there remains from 13 to 19 years to appropriate, develop, and put to use additional local water resources which are subject to the laws of appropriation. Although the applications listed in Appendix A indicate that an aggregate amount approaching 26,000 acre-feet have been applied for since February 7, 1957, the quantity of water actually developed and used since that time is minute compared to the 33,000 acre-feet allowed.

Time is, therefore, of the essence in developing additional local water resources subject to the laws of appropriation. After full beneficial use is made of the yield from Monticello Reservoir, the right to such appropriation presumably will be terminated. This does not necessarily mean that additional supplies could not be secured in the future for use in the upper basin. Plans for transporting huge quantities of water from the Eel River Development through the Upper Putah Creek Basin to the Delta have been and are currently being studied. It is possible that water could be obtained from that source for use in the upper basin. However, even if Eel River water does not become available, it is possible that water could be made available for development in the upper basin through exchanges with downstream users on the valley floor.



ESTIMATED BUILD-UP OF DEMAND FOR WATER
IN SOLANO PROJECT SERVICE AREA

CHAPTER III. SURFACE WATER SUPPLY

The principal source of water supply in the Upper Putah Creek Basin originates from direct precipitation on the area, occurring almost entirely in the form of rainfall. The magnitude of precipitation and resultant runoff varies over a wide range throughout the area and erratically from year to year. However, there are numerous springs which maintain a limited flow throughout the summer. Small quantities of surface water are utilized through direct diversion of stream flow and small surface storage developments. In addition some surface water percolates to ground water bodies which are utilized to a limited extent in certain portions of the basin. There has been no importation of water to the area.

Precipitation

The Upper Putah Creek Basin lies within the area traversed by the southern portion of storms which sweep inland from the Pacific Northwest during the winter and spring months. The precipitation from these storms varies from moderate to heavy and, due to the lifting effect, generally increases with increases in land elevation. Pronounced and abrupt changes in altitude and topography have marked effects on the quantity of precipitation.

Records of Precipitation

The report on the Putah Creek Cone Investigation listed six precipitation stations within the Upper Putah Creek Basin with records exceeding ten years in length and presented a isohyetal map showing the estimated mean seasonal depth of precipitation over the basin. Since the publication of that report, two new stations have been established near Monticello Reservoir to replace a former station. There have been no other new precipitation stations established in the basin. However, extensive investigations of precipitation were made in the adjacent areas during the recently completed Cache Creek Basin Investigation and the continuing North Coastal Development Investigation. Studies for these investigations supply data believed to be indicative of conditions in the Putah Creek Basin. Because of the time and funds available the precipitation characteristics in the basin were based on the data available from these prior investigations.

Table 11 lists precipitation stations located both within the basin and on the outside slopes adjacent to the basin. Most of the stations listed have continuous records of ten years or longer. Mean conditions of water supply were assumed to be represented by the 50-year period 1905-06 - 1954-55. Where necessary, precipitation records were extended to cover the 50-year mean period by correlation with records of nearby stations covering the longer period.

MEAN, MAXIMUM, AND MINIMUM SEASONAL PRECIPITATION
AT SELECTED STATIONS IN AND NEAR
UPPER PUTAH CREEK BASIN

Station	County	General Location Reference-MDB&M Township	Range	Section	Elevation, in feet	Source of record a/	Period of record	Estimated or recorded mean seasonal precipitation in inches of depth	Recorded maximum and minimum seasonal precipitation: Season	In inches of depth
				WITHIN UPPER PUTAH CREEK BASIN						
Aetna Springs	Napa	9N	6W	1	798	Private	1924-1938	34.59	1937-38 1930-31	58.02 17.96
Cobb	Lake	11N	8W	10	2,500	Private	1923 to date	60.30	1957-58 1923-24	115.37 22.38
Guenoc Ranch	Lake	10N	6W	3	1,200	Private	1931-1939	44.03	1937-38 1931-32	49.55 14.43
Harbin Springs	Lake	11N	7W	20	1,950	Private	1933-1939	45.60	1937-38 1936-37	83.58 32.86
Helen Mine	Lake	10N	8W	1	2,760	USWB	1900-1922	82.66	1908-09 1917-18	126.29 49.38
Holbergs	Lake	12N	8W	35	2,980	USWB	1931 to date	50.80	1937-38 1938-39	112.50 30.09
Middletown	Lake	10N	7W	3	1,122	USWB	1938 to date	44.43	1955-56 1958-59	76.98 29.68
Monticello	Napa	9N	3W	32	350	Private	1913-1947	21.92	1940-41 1919-20	41.67 10.76
Mt. St. Helena	Napa	9N	7W	2	2,300	USWB	1901-1912	54.60	1906-07 1911-12	79.56 32.44
Silverado Ranch	Napa	9N	7W	11	2,380	Private	1927-1939	60.87	1935-36 1930-31	79.61 28.00

TABLE 11 (continued)

MEAN, MAXIMUM, AND MINIMUM SEASONAL PRECIPITATION
AT SELECTED STATIONS IN AND NEAR
UPPER PUTAH CREEK BASIN

Station	General Location				Elevation, in feet	Source of record a/	Period of record	Estimated or recorded mean seasonal precipitation in inches of depth	Recorded maximum and minimum seasonal precipitation	
	County	Reference-MDB&M								
		Township	Range	Section					Season	In inches of depths
ADJACENT TO UPPER PUTAH CREEK BASIN										
Angwin P. V. College	Napa	38°35'	122-26		1,815	PUC	1940- 1958		1957-58 1946-47	65.81 23.97
Brooks Farnham	Yolo	11N	3W	36	350	USWB	1921 to date	20.18	1940-41 1923-24	44.86 9.61
Calistoga	Napa	9N	7W	36	365	USWB SPRR	1873 to date	33.35	1889-90 1923-24	67.51 12.16
Capay 1 W	Yolo	10N	2W	15	250	Private	1945- 1958	20.35	1957-58 1956-57	34.62 12.63
Capay 3WNW	Yolo	10N	2W	17	250	Private	1949- 1956	18.17	1951-52 1954-55	27.47 12.84
Capay 4W	Yolo	10N	2W	20	290	Private	1889 to date	21.92	1940-41 1919-20*	47.37* 9.92*
Dunnigan 5WSW	Yolo	12N	2W	26	310	Private	1915- 1940	17.30	1937-38 1938-39	28.74 6.68
Esparto	Yolo	10N	1W	30	190	Private	1915-38 1948 to date	17.07	1957-58 1930-31	32.85 8.31
Esparto Misson Ranch	Yolo	10N	2W	34	350	Private	1924-39 1947-58	19.51	1937-38 1938-39	36.77 10.00

MEAN, MAXIMUM, AND MINIMUM SEASONAL PRECIPITATION
AT SELECTED STATIONS IN AND NEAR
UPPER PUTAH CREEK BASIN

Station	General Location: County	General Location: Reference-MDB&M: Township	General Location: Reference-MDB&M: Range	General Location: Reference-MDB&M: Section	Elevation, in feet	Source of record a/	Period of record	Estimated or recorded mean seasonal precipitation in inches of depth	Recorded maximum and minimum seasonal precipitation: Season	Recorded maximum and minimum seasonal precipitation: In inches of depths
ADJACENT TO UPPER PUTAH CREEK BASIN (continued)										
Guinda	Yolo	11N	3W	4	386	USWB and Private	1896-1939	20.56	1957-58 1923-24	38.52 9.92
Kellog	Sonoma	9N	7W	9	1,800	SCFC and WCD USWB	1936 to date	41.62	1940-41 1938-39	73.94 27.05
Kelseyville	Lake	13N	9W	14	1,385	USWB	1931 to date	24.72	1957-58 1938-39	42.68 11.77
Kelseyville 2N	Lake	13N	9W	2	1,360	UC	1935-1953	23.41	1940-41 1938-39	41.49 13.18
Lower Lake 1W	Lake	12N	7W	4	1,450	Private	1935 to date	27.16	1957-58 1938-39	68.60 11.13
Lytton 4NE	Sonoma	10N	9W	23	500	SCFC and WCD	1938 to date	36.03	1957-58 1938-39	73.10 18.91
Napa Hospital	Napa	38°17'	122-16		60	Private	1877 to date		1940-41 1938-39	42.06 12.27
Rumsey	Yolo	12N	3W	18	420	Private	1937 to date	23.02	1940-41 1938-39	44.68 8.94
Rumsey 1NW	Yolo	12N	4W	12	455	Private	1928 to date	24.16	1940-41 1938-39	47.66 9.82
The Geysers	Sonoma	11N	9W	23	125	USWB	1949 to date	35.99	1957-58 1949-50	97.64 39.12

TABLE 11 (continued)

MEAN, MAXIMUM, AND MINIMUM SEASONAL PRECIPITATION
AT SELECTED STATIONS IN AND NEAR
UPPER PUTAH CREEK BASIN

Station	General Location				Elevation, in feet	Source of record a/	Period of record	Estimated or seasonal mean seasonal precipitation	Recorded maximum and minimum seasonal precipitation	
	County	Reference-MDB&M								
		Township	Range	Section					Season	In inches of depths
ADJACENT TO UPPER PUTAH CREEK BASIN (continued)										
Upper Lake R.S.	Lake	15N	9W	7	1,343	USWB	1932 to date	33.57	1957-58 1938-39	60.94 21.60
Vacaville	Solano	6N	1W	17	175	USWB	1880 to date	24.22	1889-90 1938-39	50.05 9.90
8 Veterans Home	Napa	6N	5W	1	170	SCFC and WCD	1911 to date		1940-41 1938-39	62.59 11.28
Winters	Yolo	8N	1W	15	132	USWB	1942 to date	17.36	1957-58 1946-47	34.65 12.68
Winters 1WSW	Yolo	8N	1W	29	140	Private	1931 to date	20.65	1940-41 1938-39	46.52 8.19
Winters 5SW	Solano	7N	2W	12	240	Private	1938-1954	23.67	1940-41 1938-39	52.86 10.49
Winters 3NE	Yolo	8N	1E	13	116	Private	1926 to date	17.61	1940-41 1938-39	37.67 6.83
Winters Scott Ranch	Yolo	9N	[illegible]S	26	320	Private	1950 to date	21.19	1957-58 1954-55	36.49 14.57

a/ USWB - U. S. Weather Bureau; SPRR - Southern Pacific Railroad; UC - University of California; SCFC and WCD - Sonoma County Flood Control and Water Conservation District; PUC - Pacific Union College.

* Also in 1954-55

Characteristics of Precipitation

Rainfall constitutes practically all precipitation in the area although light snowfall is not uncommon at the higher elevations of the westerly portion of the basin. Storms passing over the basin deposit their heaviest precipitation along the crest of the ridge defining the westerly boundary of the basin. As the storms progress eastward, depth of precipitation generally decreases with decreases in elevation until a minimum is reached in the vicinity of Lake Berryessa. Once having passed over the lake, the lifting effect of the mountains forming the easterly boundary cause only a slight increase in the seasonal depth of precipitation because the productivity of most of the storms has been largely dissipated.

Precipitation varies over wide limits from year to year. The estimated mean annual depth of precipitation over the entire basin is about 33.5 inches, varying from a minimum of about 22 inches near Lake Berryessa to a maximum of over 80 inches at Helen Mine, located near the ridge tops between Cobb Mountain and Mount St. Helena.

Over 95 percent of the annual precipitation occurs, on the average, during the 7-month period from October through April. Estimated average monthly distribution of mean annual precipitation at Middletown is shown in Table 12.

TABLE 12

ESTIMATED AVERAGE MONTHLY DISTRIBUTION OF
MEAN ANNUAL PRECIPITATION AT MIDDLETOWN

Month	Depth of Precipitation: Inches	Depth of Precipitation: Percent of Seasonal Total	Month	Depth of Precipitation: Inches	Depth of Precipitation: Percent of Seasonal Total
October	2.53	5.70	April	3.40	7.65
November	5.38	12.12	May	1.30	2.93
December	10.72	24.13	June	0.46	1.04
January	8.54	19.21	July	0.02	0.04
February	6.16	13.86	August	.00	.00
March	5.81	13.08	September	0.11	0.24
			TOTALS	44.43	100.00

Runoff

The major source of surface runoff within the Upper Putah Creek Basin results from rainfall on the highly productive watersheds of the Mayacmas Mountains located in the upper reaches of the basin. Streams in this watershed are of three types: intermittent, ephemeral and perennial interrupted. Intermittent streams are those which flow during prolonged periods, but not continuously. Ephemeral streams are defined as those which flow only in direct response to rainfall. Perennial streams are those which flow continuously. Perennial interrupted streams are those which have perennial reaches with intervening intermittent or ephemeral reaches.

The upper reaches of Putah Creek, St. Helena Creek, Dry Creek, James Creek, Swartz Creek and Big Canyon Creek are examples of the intermittent type. Most minor tributaries are of the ephemeral type. Putah Creek is an example of the perennial interrupted type. This stream contains reaches in which the flow is continuous. These reaches are typically in canyons through nonwater-bearing formations and are interrupted by ground water basins which discharge seepage flow at the lower end and which absorb stream flow by seepage into the sands and gravels at the upper end. Two such reaches are located in the canyon between Collayomi and Coyote Valleys and in the canyon just below Coyote Valley, respectively. The latter case is substantiated by over 30 years of continuous record at the U.S.G.S. stream gaging station near Guenoc.

Stream Gaging Stations and Records

The earliest runoff records available in the Upper Putah Creek Basin were obtained in February, 1904, when a staff gage was established by the United States Geological Survey on "Putah Creek near Guenoc". This station was maintained until July, 1906, when it was discontinued. However, this station was reestablished by the installation of a water-stage recorder in July of 1930 and has remained in continuous operation since that time.

In September, 1905, a staff gage was established on "Putah Creek at Winters" and remained in continuous operation until September, 1931. Although this station was not located in the Upper Putah Creek Basin, it provides a good indication of the total runoff originating in the basin since there are only relatively minor tributaries between the basin boundary and the location of this station.

In July, 1930, a permanent gaging station equipped with a water-stage recorder was established on "Putah Creek near Winters" located about 6 miles upstream from the "at Winters" station. The "near Winters" station was established to replace the "at Winters" station.

More recently, stream gaging stations have been installed on tributary streams within the basin at Dry Creek near Middletown and Pope Creek near Pope Valley on May, 1959, and December, 1960, respectively.

Other gaging stations, although not within the Upper Putah Creek Basin, are located in adjacent or downstream tributary watersheds and are indicative of the runoff pattern for portions of the Upper Putah Creek Basin. These include Kelsey Creek near Kelseyville, which has had a water stage recorder in continuous operation since October, 1947; Highland Creek near Kelseyville, which has been recording water stages since October, 1954; Adobe Creek near Kelseyville also has been recording water stages since October, 1954; Salt Creek near Winters where a water stage recorder was in operation from October 1951 to September 1954; and Pleasants Creek near Winters where a recorder was in operation from November 1951 to June 1954.

Locations of the stations in the basin are shown on Plate 3, "Locations of Wells Canvassed", and pertinent data for these stations are listed in Table 13.

TABLE 13

STREAM GAGING STATIONS IN, OR RELATED TO, UPPER PUTAH CREEK BASIN

Stream and station	Location[a]			Drainage area, in square miles	Period of record	Source of record
	Section	Township	Range			
Dry Creek, near Middletown	8	10N	7W	8.4	May 1959 to date	USGS[b]
Putah Creek, near Guenoc	27	11N	6W	112	February 19 through July 1906, July 1930 to date	USGS
Pope Creek, near Pope Valley	18	9N	4W	78	December 1960 to date	DWR[c]
Putah Creek, near Winters	28	8N	2W	577	July 1930 to date	USGS
Putah Creek, at Winters	22	8N	1W	634	September 1905 through September 1931	USGS
Kelsey Creek, near Kelseyville	34	13N	9W	37.4	October 1947 to date	USGS
Highland Creek, near Kelseyville	31	13N	9W	12.7	October 1954 to date	USGS
Adobe Creek, near Kelseyville	5	12N	9W	6.4	October 1954 to date	USGS
Salt Creek, near Winters	25	9N	2W	10.8	October 1951 to September 1954	DWR
Pleasants Creek, near Winters	1	7N	2W	16.2	November 1951 to June 7, 1954	DWR

a/ Mount Diablo Base and Meridian
b/ United States Geological Survey
c/ Department of Water Resources

12. Recently constructed stream gaging station on Dry Creek near Middletown. This gaging station is maintained by the U. S. Geological Survey.

13. Recently constructed stream gaging station on Pope Creek near Pope Valley. This installation was made by the Department of Water Resources.

Runoff Characteristics

Runoff from streams in the Upper Putah Creek Basin has historically varied within wide limits from month to month and from year to year. Annual natural runoff of Putah Creek near Winters has varied from a maximum of about 444 percent of the mean in 1940-41 to a minimum of about 16 percent of the mean in 1930-31. For this study, mean conditions of water supply were assumed to be represented by the 50-year period 1905-06 - 1954-55. Almost 98 percent of annual runoff occurs, on the average, during the 7-month period from November through May. The estimated average monthly variation in mean annual natural runoff for Putah Creek near Guenoc and Putah Creek near Winters is shown in Table 14.

In contrast to the similarity of occurrence of precipitation and runoff, about 90 percent of the average demand for irrigation water occurs during the 5-month period from May through September. This incompatable occurrence of water supply and demand is shown graphically in Figure 4 which illustrates one of the basic water problems in the Upper Putah Creek Basin.

Quantity of Runoff

Records of runoff for the entire length of the 50-year mean period are not available for a single location in the basin. In early U.S.G.S. water supply papers the "at Winters" and "near Winters" gaging stations on Putah Creek were listed as "equivalent" or "practically equivalent" and were treated as such in past studies. More recently, in the "Survey's Compilation of Surface Water Records," published in 1959, a revision is found which states that records for the station near

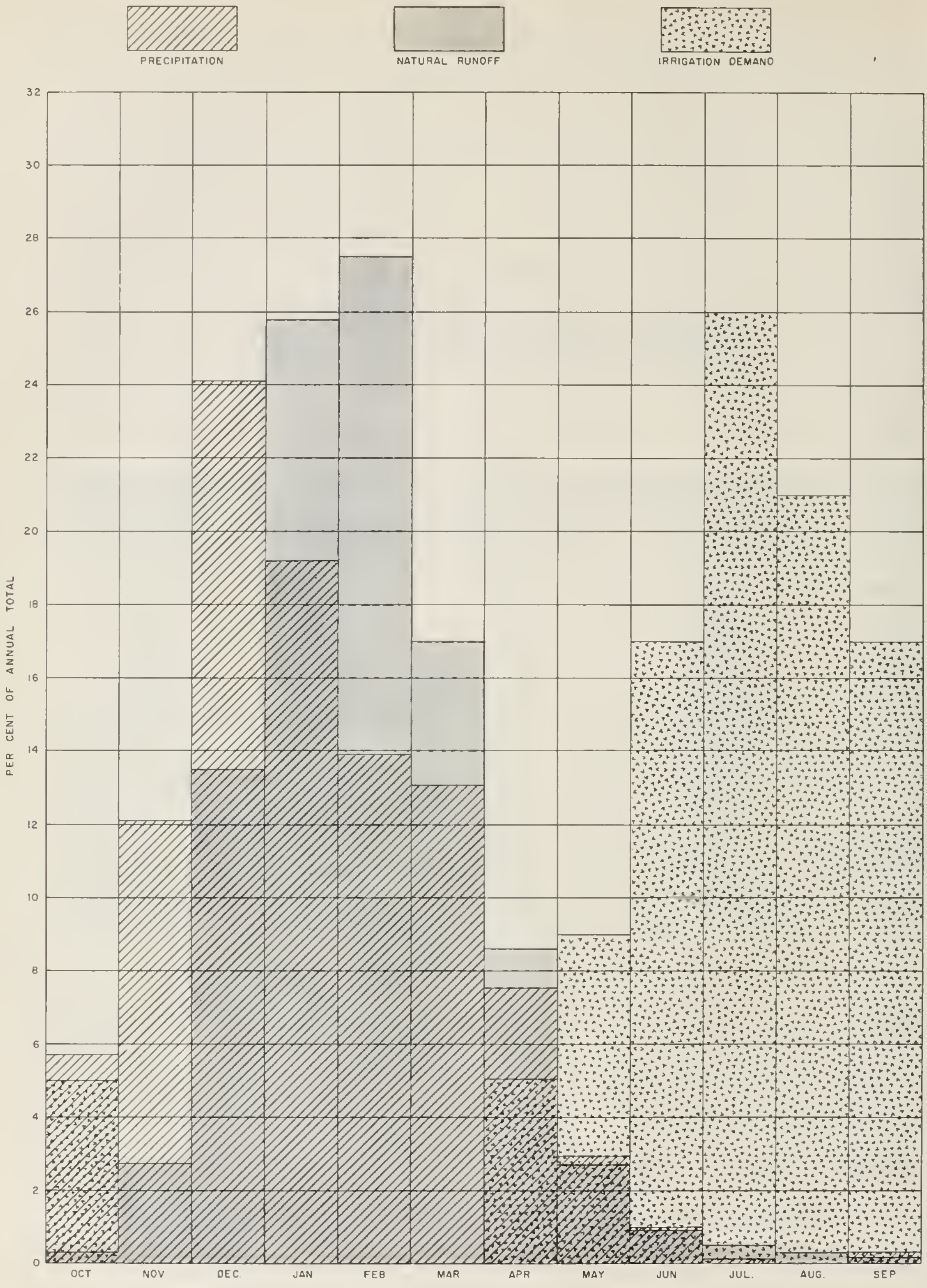
Winters are not equivalent to records for the station at Winters. Studies for this investigation have indicated that the two primary factors affecting this lack of equivalence are intermediate tributary runoff and stream flow percolation to ground water. These two factors act in opposite directions but are not entirely compensatory. During periods of high runoff, intermediate tributary runoff exceeds percolation losses while during periods of low runoff percolation losses exceed intermediate tributary runoff. Therefore, for the purpose of establishing records of runoff at a long-term base station to use as a basis for extending the records at Putah Creek near Guenoc over the entire 50-year mean period, runoff of Putah Creek for the station near Winters for the period 1905-06 through 1929-30 was estimated by adjusting records for the station at Winters for the effects of intermediate runoff and percolation losses. Adjustments were also made for the effects of historical upstream impairments so that the flows would represent natural conditions. Figure 5 shows the estimated relationship between recorded runoff of Putah Creek near Winters and Putah Creek at Winters. Table 15 presents the recorded and estimated natural total annual quantities of runoff originating in the Upper Putah Creek Basin.

From studies of upstream irrigation uses and by correlation with the estimates of natural flow of Putah Creek near Winters, records of runoff at Putah Creek near Guenoc were adjusted for upstream impairments and extended over the 50-year mean period. Table 16 presents the recorded and estimated natural annual runoff of Putah Creek near Guenoc. It is noteworthy that the mean annual natural runoff of 144,400 acre-feet at the Guenoc station represent about 41 percent of the total mean

TABLE 14

ESTIMATED AVERAGE MONTHLY DISTRIBUTION OF MEAN ANNUAL NATURAL RUNOFF OF PUTAH CREEK NEAR GUENOC AND PUTAH CREEK NEAR WINTERS

Month	Putah Creek near Guenoc		Putah Creek near Winters	
	In acre-feet	In percent of mean annual	In acre-feet	In percent of mean annual
October	400	0.3	800	0.2
November	3,900	2.7	7,300	2.1
December	19,500	13.5	43,800	12.6
January	37,100	25.7	89,500	25.7
February	39,700	27.5	99,200	28.5
March	24,600	17.0	62,100	17.8
April	12,400	8.6	30,100	8.7
May	3,900	2.7	8,900	2.6
June	1,500	1.0	3,200	0.9
July	700	0.5	1,400	0.4
August	400	0.3	900	0.3
September	300	0.2	700	0.2
TOTALS	144,400	100.0	347,900	100.0



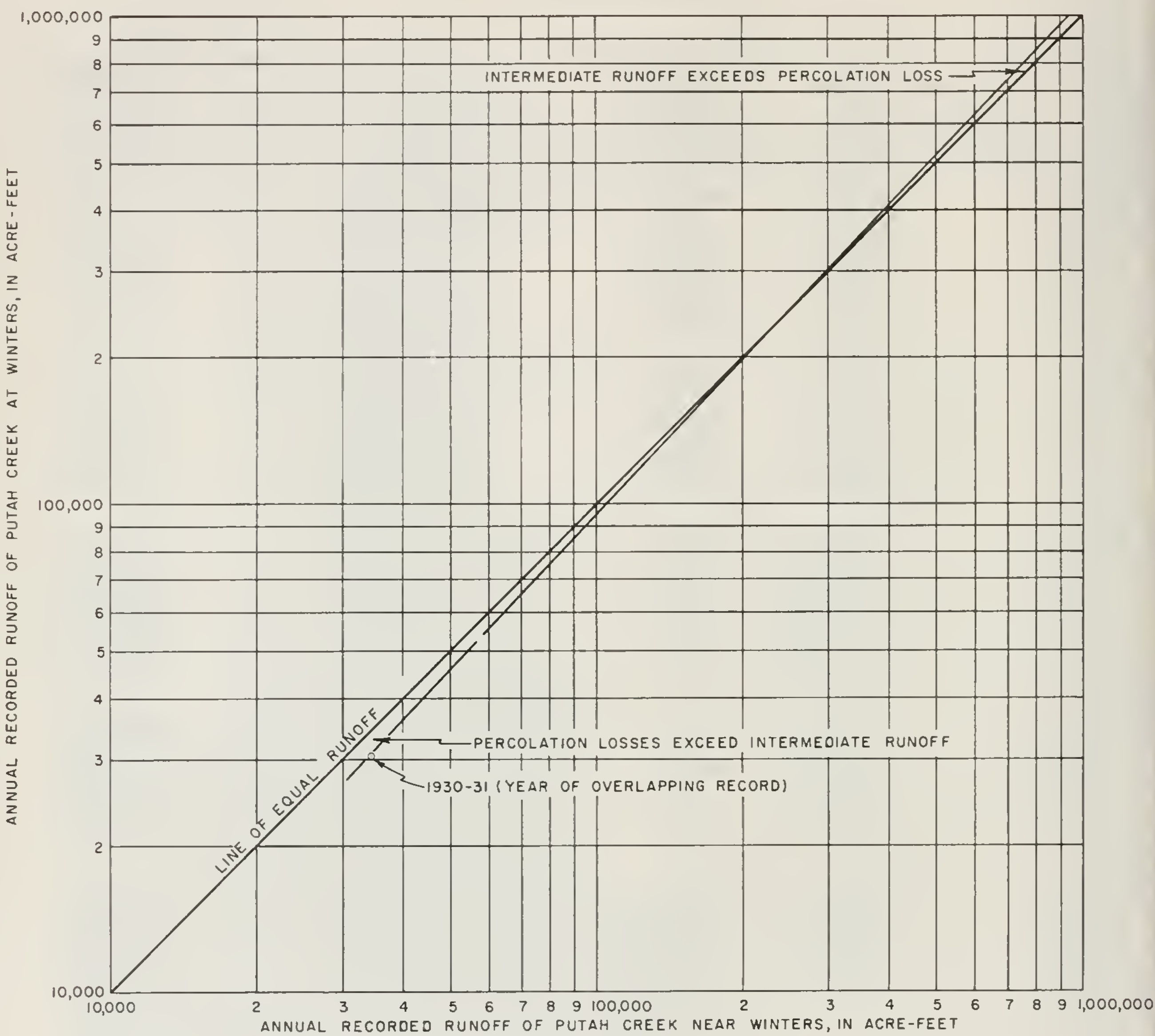
RELATIONSHIP BETWEEN THE AVERAGE OCCURRENCE OF PRECIPITATION, RUNOFF, AND IRRIGATION DEMAND

TABLE 15

RECORDED AND ESTIMATED NATURAL ANNUAL RUNOFF OF PUTAH CREEK
ORIGINATING IN THE UPPER PUTAH CREEK BASIN

(In acre-feet)

Water year	Recorded runoff		Estimated natural runoff near Winters	Water year	Recorded runoff		Estimated natural runoff near Winters
	Near Winters	At Winters			Near Winters	At Winters	
1905-06		582,600	560,900	1930-31	34,800	30,200	38,700
-07		690,800	656,500	-32	200,700		205,600
-08		199,400	203,800	-33	94,600		100,000
-09		881,200	823,800	-34	145,500		149,900
-10		227,700	231,800	-35	352,300		357,700
1910-11		492,800	481,200	1935-36	346,500		351,400
-12		59,200	65,000	-37	280,000		285,400
-13		133,500	139,400	-38	853,400		860,200
-14		895,300	835,900	-39	41,600		45,700
-15		709,700	672,300	-40	674,700		683,800
1915-16		708,800	672,200	1940-41	1,004,000		1,011,200
-17		284,400	288,300	-42	715,200		722,600
-18		88,800	97,100	-43	319,400		325,400
-19		315,500	318,500	-44	178,200		184,300
-20		42,500	51,000	-45	206,500		213,900
1920-21		509,200	501,000	1945-46	261,700		269,200
-22		230,200	236,000	-47	129,400		137,000
-23		278,200	283,700	-48	133,300		140,800
-24		38,600	47,500	-49	192,100		199,800
-25		348,400	351,500	-50	182,100		189,600
1925-26		347,900	350,200	1950-51	388,000		396,800
-27		544,200	531,700	-52	588,000		596,800
-28		300,500	303,300	-53	423,400		431,200
-29		66,300	75,600	-54	284,200		295,300
-30		322,000	326,600	-55	92,800		99,100
			Average for period of record		324,900	358,800	. .
			50-year mean				347,900



ESTIMATED RELATIONSHIP BETWEEN RUNOFF OF
PUTAH CREEK NEAR WINTERS AND PUTAH CREEK AT WINTERS

TABLE 16

RECORDED AND ESTIMATED NATURAL ANNUAL RUNOFF
OF PUTAH CREEK NEAR GUENOC

(In acre-feet)

Water year	Runoff: Recorded	Runoff: Estimated natural	Water year	Runoff: Recorded	Runoff: Estimated natural
1904-04	224,000	*			
1905-06	263,000	263,100	1930-31	23,500	24,700
-07		248,400	-32	83,100	84,500
-08		98,200	-33	51,800	53,200
-09		297,900	-34	78,600	80,100
-10		108,800	-35	141,500	143,200
1910-11		194,400	1935-36	157,900	159,400
-12		38,400	-37	109,700	111,500
-13		72,400	-38	337,800	339,800
-14		301,900	-39	26,400	28,000
-15		253,400	-40	242,700	245,200
1915-16		253,500	1940-41	320,900	323,400
-17		129,500	-42	261,600	263,800
-18		54,300	-43	131,900	133,700
-19		140,100	-44	81,300	83,100
-20		31,000	-45	95,300	97,500
1920-21		200,900	1945-46	116,800	119,300
-22		110,400	-47	79,100	81,400
-23		127,800	-48	85,400	87,600
-24		28,600	-49	95,400	97,800
-25		151,300	-50	85,600	87,900
1925-26		151,100	1950-51	173,600	176,600
-27		210,500	-52	222,000	224,300
-28		134,700	-53	185,200	187,600
-29		44,300	-54	134,400	136,500
-30		142,800	-55	60,500	62,600
		Average for period of record		143,300	
		50-year mean			144,400

*Not included as part of 50-year mean period.

annual natural runoff of 347,900 acre-feet originating in the Upper Putah Creek Basin, although the drainage area tributary to this station is only about 20 percent of the total area. These natural flow studies, together with records of runoff at the short-term stations in and adjacent to the basin and studies of rainfall-runoff relationships provided the basis for estimating surface inflow to and potential annual yield from the possible reservoir sites discussed in a later portion of this bulletin.

Flood Flows

No significant flooding problems exist on any of the streams tributary to Putah Creek in the upper basin. Minor remedial measures to prevent flood damage have been limited to bank protection and channel construction works, principally on Dry and St. Helena Creeks near the town of Middletown. The gravel channels which traverse the valleys contain no improvements and no improvements of major value in the limited areas of flooding are expected to occur in the future. Therefore, since there appears to be no need for flood control measures, such features were not included as a project function for any of the surface storage sites investigated. However, in order to determine required spillway capacities and freeboard allowances for all the reservoirs considered, studies were made of the magnitudes of the maximum probable floods that could occur at each site.

The probable maximum flood is defined as the flood that would result from the most critical combination of precipitation distribution, snowmelt, and infiltration losses that would probably occur within a particular hydrologic region under present climatic conditions. Flood hydrographs were derived using the estimated 72-hour maximum probable precipitation, and unit hydrographs developed for gaged areas in and adjacent to the basin. Loss rates were based on data from similar studies previously made for adjacent areas.

It was assumed that spillways should be large enough to pass the maximum probable flood without over-topping the dam. This requirement was satisfied by routing studies in which nominal allowances for total and residual freeboard were included.

Water Quality

The quality of water may be defined as the characteristics of water affecting its suitability for beneficial use. Because of the reconnaissance nature of this investigation and the availability of water quality data and findings contained in the report on the Putah Creek Cone Investigation, no new water quality data were developed for this investigation. A brief summary of these water quality findings is contained in this bulletin.

General Water Quality Conditions

Surface waters in the Upper Putah Creek Basin are predominately magnesium-bicarbonate in character and suitable for all beneficial purposes. Analyses of 19 surface water samples showed that the mineral quality of all streams sampled improved with increase in rate of discharge. The analyses also indicated that mineral quality in streams in the upper reaches of the basin, above the principal potential places of use, is superior to that in the lower reaches of the basin. This is due to the lesser dilution of rainfall with the more mineralized base flows of lower tributaries which, in general, have a smaller total unit runoff.

Water Quality Problems

The most general and widespread water quality problem of domestic users appears to be excessive hardness. This is principally due to calcium and magnesium which results in increased soap consumption, more frequent repairs to plumbing, and the necessity or desirability of maintaining water softening appliances. The effect of hardness on soap consumption can be somewhat overcome by use of synthetic detergents.

In some local areas boron concentrations are very high, making the water unsuitable for irrigation on all except the most tolerant crops. This condition is most pronounced during low flows of Soda Creek, and in significant quantities in moderate flows of Eticuera and Capell Creeks.

Surface storage reservoirs would tend to reduce these concentrations by mixing and diluting the more mineralized low flows with the better quality rainfall-fed high flows. However, at such time as a specific project is selected for development, additional water samples at the selected site should be collected and analyzed for both high and low flow conditions. If tailings from mining operations exist in the watershed above the selected site and the developed supply is to be used for domestic purposes, the analyses of water samples for heavy metals should be included.

CHAPTER IV. GROUND WATER POTENTIAL

Ground water reservoirs provide for natural regulation of available water resources. They also may convey water from places of recharge to widely dispersed places of extractions, and thereby make water accessible over a wide area. When geologic and hydrologic conditions are favorable, development of a ground water supply can have several advantages over development of a surface water supply. Some of the most common advantages are: (1) readily available storage capacity susceptible to staged development; (2) relatively low initial capital investment; and (3) elimination or reduction of the need for distribution facilities.

Development of ground water in the Upper Putah Creek Basin may also have some legal advantage over surface water development. The right of a landowner to develop water from a ground water supply for reasonable beneficial use on overlying land is not derived by appropriation. These rights are similar to riparian rights and are paramount to the appropriative rights issued to the Bureau of Reclamation for operation of the Solano Project. For this reason, the quantitative and time limitations on future appropriations of water for upstream use, as set forth in the terms of the bureau's water right permits, are not applicable to such ground water development.

It should be understood, however, that the water right advantage of ground water development is subject to the following limitations: (1) extracted ground water is subject to reasonable beneficial uses on overlying land; (2) water withdrawn from a ground water supply tributary to Putah Creek for use on nonoverlying land is subject to the limitations in the bureau's water right permits; (3) recharge of the ground water supply is limited to natural infiltration and percolation of surface waters; and (4) artificial recharge of the ground water supply by percolation, facilitated by temporary storage of surface water in spreading basins, would constitute an appropriation of water subject to the jurisdiction of the State Water Rights Board. For these reasons, the advantages of ground water development are limited to landowners where the many conditions favorable to ground water development are satisfied.

Studies of the ground water potential in the Upper Putah Creek Basin included a reconnaissance appraisal of factors which affect ground water occurrence, movement, utilization, and recharge. The geologic investigations included the collection, compilation, and interpretation of existing well drillers' logs, published and unpublished geologic reports and maps, and the determination of location, extent, and physical characteristics, of water-bearing deposits in the area. The study of ground water utilization was limited to the principal alluvial valleys. About 210 wells were located during this investigation. These are shown on Plate 3, "Locations of Wells Canvassed". Data collected on these wells included pump tests, type and size of pumping plant equipment, diameter and depth of casing, principal use and age of well, and ownership. Measurements were made of depth to water in 123 and 144 wells in the fall of 1960 and the spring of 1961, respectively. The study of ground water recharge in the major valley areas included several instantaneous stream flow measurements to determine infiltration rates for various reaches of stream channels and an analysis of water level and well log data to estimate change in ground water storage during the winter of 1960-61.

Reliable estimates of cost of developing additional supplies from planned operation of ground water storage could not be determined from available data. Although it is fairly easy to estimate the cost of a well equipped with a pump and motor, it is not possible to predict in advance, with any degree of certainty, the yield obtainable from a prospective well. Nor is it known how many dry holes might have to be drilled for every good producing well obtained. Cost comparisons of ground water versus surface water development could not, therefore, be made.

Occurrence of Ground Water

Most of the materials that comprise the earth's surface have open spaces which may contain water. These spaces range in size from minute pores in clays to large fractures and joints found in crystalline and consolidated sedimentary rocks. Depending upon the distribution and size of such openings, the movement and volume of ground water may vary from near zero to high values.

Ground water, by definition, refers only to that water which occurs below the water table, within the zone of saturation. Within this zone all the open spaces in subsurface materials are filled with ground water. Nearly all ground water is derived initially from precipitation.

Ground water may be either unconfined or confined. When the upper surface of the zone of saturation forms a water table under atmospheric pressure, ground water is said to be unconfined. Under this condition, changes in volume of stored ground water cause the water table to rise and fall. Ground water contained in a saturated aquifer directly overlain by sediments of markedly less permeability is said to be confined ground water. Where water is confined the rise and fall of water levels in wells represent changes in pressure within the aquifer. Since the ability of a porous material to transmit water is relative, confinement is also relative.

Geology

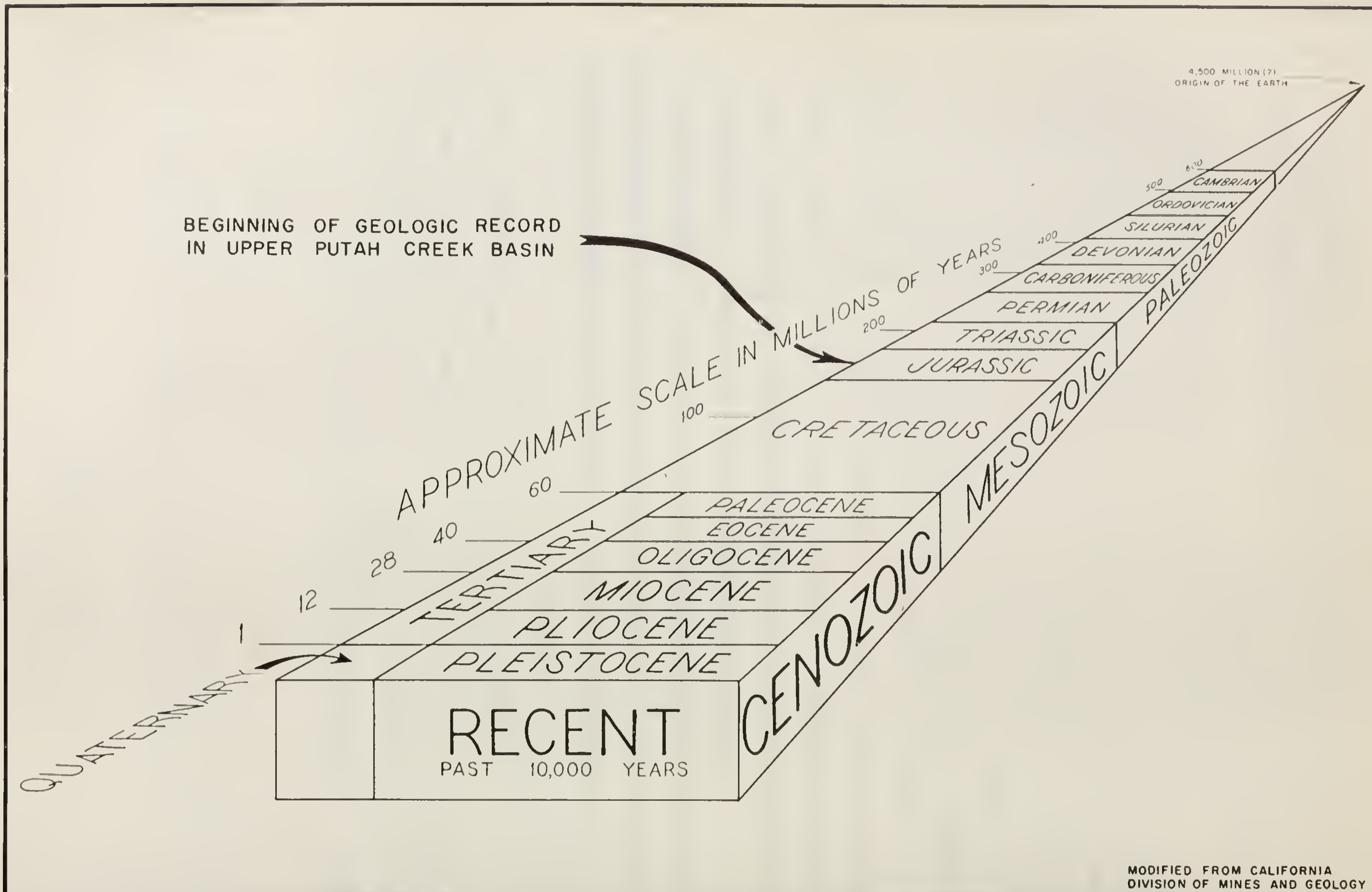
A knowledge of the geology of the area is the key to understanding present ground water conditions and the possibilities for further development of ground water in the Upper Putah Creek Basin. Figure 6, "Looking Back In Geologic Time", presents an illustration of the various components of geologic time. The largest time unit is the era. The three principal eras are the Cenozoic (the most recent), the Mesozoic, and the Paleozoic. All of the rocks and sediments which make up the land forms in the Upper Putah Creek Basin were deposited during the Mesozoic and Cenozoic eras. An era is divided into periods, which are further subdivided into epochs, as shown in Figure 6.

The table shows a stratigraphic column of the rocks and sediments in the Upper Putah Creek Basin. In this column, all of the geologic units are stacked on top of each other in ascending chronologic order. The relative age and thickness of each formation may be ascertained, as well as a brief description of the physical and water-bearing properties of each formation. The areal extent of these formations is shown on Plate 4, "Regional Geology".

The Upper Putah Creek Basin lies in the midst of the Coast Ranges geomorphic province. The basin has been carved into a bedrock complex composed of nonwater-bearing marine Mesozoic and early Cenozoic sedimentary and metamorphic rocks which have been intruded locally by basic igneous rocks. All of these rocks are capped locally by water-bearing Cenozoic volcanic and sedimentary rocks. The Mesozoic rocks are represented by the Franciscan-Knoxville groups and the undifferentiated Cretaceous sediments. The Martinez and Cache formations and the Sonoma and Clear Lake volcanics compose the bulk of the Cenozoic rocks. Recent alluvium, terrace deposits, and landslide debris occur locally.

In general, the Franciscan-Knoxville groups, the Cretaceous sediments, and the Martinez formation are complexly folded and often faulted. Extensive masses of serpentine occur along the fault zones in the Franciscan-Knoxville rocks. The other geologic formations generally are only slightly deformed.

The rock units were briefly studied to ascertain their water-bearing properties. In the following paragraphs, the units are described briefly and a generalized statement of their hydrologic properties is made. The nonwater-bearing formations are described first.



LOOKING BACK IN GEOLOGIC TIME

TABLE 11

GEOLOGIC FORMATIONS IN UPPER PUTAH CREEK BASIN

GEOLOGIC AGE			GEOLOGIC FORMATION	STRATIGRAPHY AND SYMBOL USED ON GEOLOGIC MAP	APPROXIMATE THICKNESS IN FEET	PHYSICAL CHARACTERISTICS	WATER-BEARING CHARACTERISTICS
CENOZOIC	QUATERNARY	RECENT	LANDSLIDES	Qls	0-100	UNSTABLE MIXTURE OF ROCK AND SOIL	MODERATELY PERMEABLE. PROVIDES SMALL AMOUNTS OF WATER TO SPRINGS
CENOZOIC	QUATERNARY	RECENT	ALLUVIUM	Qal	0-400	UNCONSOLIDATED TO SEMI-CONSOLIDATED SAND AND SILT WITH LENSES OF CLAY AND GRAVEL. MAY CONTAIN CEMENTED ZONES AND ORGANIC MUCK. FOUND ONLY IN VALLEY AREAS.	PERMEABILITY RANGES FROM POOR TO GOOD. MAY CONTAIN ZONES OF CONFINED WATER
CENOZOIC	QUATERNARY	RECENT – PLEISTOCENE	CLEAR LAKE VOLCANICS	Qv	100-500	VARIABLY FRACTURED DACITIC, RHYOLITIC, AND ANDESITIC LAVAS OF MT. SIEGLER, COBB MT., BOGGS MT. AND PERINI HILL	YIELDS MODERATE QUANTITIES OF WATER TO WELLS AND SPRINGS
CENOZOIC	QUATERNARY	PLEISTOCENE	CLEAR LAKE VOLCANICS, BASALT MEMBER	Qpvb	50-500	HIGHLY FRACTURED FLOWS OF OLIVINE BASALT	UNIT AS A WHOLE HIGHLY PERMEABLE. IF SITUATED IN ZONE OF SATURATION, WILL YIELD LARGE AMOUNTS OF WATER TO WELLS. ACTS AS FOREBAY FOR GROUND WATER RECHARGE
CENOZOIC	QUATERNARY	PLIO-PLEISTOCENE	TUFF	TQp	0-200	COARSE TO FINE GRAINED SANDY RHYOLITE TUFF	LOW PERMEABILITY. YIELDS SOME WATER TO SPRINGS
CENOZOIC	QUATERNARY – TERTIARY	PLIO-PLEISTOCENE	CACHE FORMATION	TQc	300-1,000+	SEMI-CONSOLIDATED CONTINENTAL DEPOSITS OF GRAVEL, SILT, AND CLAY, SOME TUFFACEOUS DEPOSITS. INTERBEDDED BASALT FLOWS AT TOP.	MODERATELY PERMEABLE, MAY YIELD SMALL TO FAIR AMOUNTS OF WATER TO WELLS AND SPRINGS
CENOZOIC	TERTIARY	PLIOCENE	SONOMA VOLCANICS	Tsv	2,000+	FLOWS OF ANDESITE AND RHYOLITE WITH INTERBEDS OF SANDY TUFF AND MUDFLOWS	GENERALLY OF LOW PERMEABILITY. SOME SANDY TUFFS YIELD GOOD QUANTITIES OF WATER TO WELLS AND SPRINGS.
CENOZOIC	TERTIARY	PALEOCENE	MARTINEZ FORMATION	Tmz	1,000+	MARINE SHALE, CONGLOMERATE, AND SANDSTONE	NONWATER-BEARING.
MESOZOIC	CRETACEOUS		CRETACEOUS SEDIMENTS, UNDIFFERENTIATED	K; dsp	10,000-15,000	K MARINE SANDSTONE AND MUDSTONE.	NONWATER-BEARING.
						dsp BLOCKS OF DETRITAL SERPENTINE IN MATRIX OF CRUSHED SERPENTINE AND SHALE.	NONWATER-BEARING.
MESOZOIC	CRETACEOUS – JURASSIC		FRANCISCAN-KNOXVILLE GROUPS, UNDIFFERENTIATED	Jfk; sch; Jbi; sp; Jb; gs	15,000+	Jfk MARINE SHALE, GRAYWACKE, CONGLOMERATE, AND CHERT	NONWATER-BEARING
						sp GREEN TO BLACK SERPENTINE, PARTLY SHEARED AND CRUSHED. CONTAINS VEINS OF WHITE MAGNESITE AND CRYSTALS OF BLACK CHROMITE	GENERALLY NONWATER-BEARING. MAY YIELD SMALL AMOUNTS OF WATER HIGH IN MAGNESIA.
						gs GREENSTONE DERIVED FROM BASIC FLOWS AND PYROCLASTICS	
						Jb BLACK PARTLY METAMORPHOSED BASALT	NONWATER-BEARING
						sch GLOUCOPHANE, ACTINOLITE, AND CHLORITE SCHIST	NONWATER-BEARING
						Jbi BLACK TO GRAY GABBRO AND DIABASE	NONWATER-BEARING

Franciscan-Knoxville Groups. The Franciscan group of Jurassic-Cretaceous age is the oldest rock unit in the basin. The rocks are principally a type of sandstone called graywacke but include a moderate proportion of interbedded shale; lesser amounts of chert and conglomerate occur in some areas. Locally these marine sediments have been intruded by serpentine. Zones of shearing and hydrothermal alteration are numerous, so that a considerable part of the sediments are sheared or contorted and contain zones of schist.

The Knoxville group overlies the Franciscan group, and consists primarily of shale, which occurs in a ratio of about 4:1 to the interbedded graywacke; conglomerate beds occur locally. The Knoxville group, like the Franciscan, is intruded by serpentine and occasionally by greenstone, but shearing of the beds is less common.

The Franciscan and Knoxville groups have been intruded by various types of basic and ultrabasic rocks. Serpentine is the most abundant of the ultrabasic intrusives, cropping out as great irregular bodies elongated in the direction of regional strike. The serpentine is generally green to greenish-black, fine-grained and ranges from hard to soft. It is generally incompetent and is frequently intensely sheared. Small intrusions of gabbro, diabase, and greenstone also occur.

In general, the sedimentary rocks of the Franciscan-Knoxville groups have low permeabilities and thus are considered nonwater-bearing. Limited amounts of water, however, may occur in fractures and joints, particularly at shallow depths. The basic and ultrabasic intrusives are also considered to be nonwater-bearing except along fractures and shear zones. Some ground water, usually high in magnesia, may be derived from the serpentine.

Cretaceous Sediments, Undifferentiated. A thick succession of massive, yellowish-brown to gray, marine sandstone and interbedded gray shale overlies the Knoxville rocks. These sediments belong to the Shasta and Chico groups of Cretaceous age. The sandstone is generally fine to medium grained with a silty matrix in beds as thick as 15 feet. The shale and mudstone are gray to grayish-brown; and fairly soft. Local deposits of conglomerate, detrital serpentine, and limestone are scattered throughout the Cretaceous section. Almost all of the rocks of Cretaceous age are nonwater-bearing. However, as in the Franciscan-Knoxville groups, some ground water may occur in fractures and joints, particularly at shallow depths.

In addition to the normal sedimentary materials, areas of detrital serpentine occur in Pope Valley, in Long Valley, and along Putah Creek north of Middletown. It has been postulated that during Cretaceous time landslides derived from submerged Jurassic serpentine bodies moved out onto the sea floor. These landslides were later covered by sediments and today appear as bodies of detrital serpentine enclosed by Cretaceous sediments. On close examination, the masses can be seen to be composed of blocks of serpentine in a matrix of crushed serpentine and black shale.

Martinez Formation. The oldest Tertiary rocks in the area are the marine sediments of the Martinez formation of Paleocene age. The formation is composed of sandstone, conglomerate and minor amounts of shale. The sandstone is white and yellow to brown and gray and is often very massive. A light gray silty shale and a poorly sorted conglomerate occur in the upper portion of the formation.

Like the older marine sediments, the Martinez formation is nonwater-bearing. It may yield very minor amounts of water from joints and fractures.

Sonoma Volcanics. The volcanic rocks which occur along the western border of the Upper Putah Creek Basin are a part of the Sonoma volcanics of Pliocene age. These are the oldest and thickest volcanic rocks in the area, and are believed to achieve a thickness of over 2,000 feet. The dominant rock types are light gray andesites and rhyolites which occur as flows, tuffs, tuff-breccias and agglomerates.

The Sonoma volcanics are partially water-bearing. In some places, the interbedded sandy tuffs are fairly permeable. The agglomerate and tuff-breccias are believed to be of minor importance to ground water storage or movement.

Cache Formation. The Cache formation of Plio-Pleistocene age consists of fresh-water deposits of gravel and silt which, in some places, underlie lava caps. Outcrops of this formation are generally light gray or yellow brown. The unit is composed of poorly consolidated gravel, silt, sand, and lesser amounts of water-laid tuff, limestone, and diatomite.

In general, most of the rocks in the Cache formation have low permeabilities except for occasional gravel and sand beds. Some wells penetrate the formation and produce moderate quantities of water.

Tuff. A thin bed of rhyolite tuff overlies the sediments of the Cache formation. The tuff usually occurs just beneath a cover of overlying basalt. It is of low permeability and is of little importance to ground water.

Clear Lake Volcanics, Basalt Member. Extensive flows of olivine basalt of Pleistocene age cap many of the hills in the Upper Putah Creek Basin. These flows are highly fractured and have a fairly high permeability. In a few places the basalt occurs at or beneath the level of various valley floors. Here, it is within the zone of saturation and should provide abundant quantities of water to wells. Some of the basalt flows are interbedded with the uppermost sediments of the Cache formation.

Clear Lake Volcanics. Rhyolite flows and tuffs, and andesitic and dacitic lavas comprise the upper part of the Clear Lake volcanic series. The lavas are of Pleistocene to Recent age and were apparently extruded from a system of northwest-trending fissures.

The lava and fragmental volcanic rocks may absorb appreciable quantities of precipitation and store it in joints and fractures. Surplus ground water emerges as small springs from open fractures or at the top of impermeable zones. Because it generally underlies rough, untillable land, very little ground water development has occurred in this unit.

Alluvium. Unconsolidated to semi-consolidated alluvium occurs extensively in the larger valleys and as narrow, sinuous deposits along streams and creeks. The alluvium may be subdivided into stream, flood-plain, lacustrine, and colluvial deposits.

The stream deposits consist of angular to rounded cobbles, gravel, and sand, and are the best water producing zones in the alluvium. However, due to their local and irregular occurrence, these are generally encountered only by chance when drilling for water.

The flood plain deposits generally occur between the stream deposits and the colluvium and consist of fine-grained sand, silt, and clay. These materials are generally more extensive than the stream deposits in occurrence but, in general, have low permeabilities.

The lacustrine deposits are found in Collayomi, Long, and Coyote Valleys; they also occur locally in other valleys. These sediments were deposited during periods when the valleys were inundated by fresh water lakes. They are generally fine-grained sand, silt, and blue clay, all of low permeability, but include some fine sand. Lacustrine deposits extend over large portions of the valleys often overlying more permeable units. Due to the low permeability and placement of these deposits, they often act as confining layers to the underlying more pervious deposits, resulting in pressure conditions.

The colluvium, which is not an alluvial deposit in the strict sense, occurs near the margins of the valleys. This weathered material moved downslope, primarily by the force of gravity. Most colluvial material which reached the valley floor is so fine-grained as to be nearly impervious.

With few exceptions, the stream deposits are the only important water bearing zones in the alluvium in the Upper Putah Creek Basin. The other alluvial deposits are comprised of relatively fine-grained sediments which yield only small quantities of water. Well production in the alluvium is quite variable and depends on the composition and thickness of the sediments. Thus, if large quantities of ground water are required, it is generally essential that buried stream gravels which lie below the water table be penetrated.

Landslides. Landslides are common throughout the area of investigation. They can be easily recognized by their topographic expression and broken rock masses. Serpentine appears to be particularly susceptible to the development of landslides. The lava flows of the Clear Lake volcanics are nearly everywhere skirted by talus slopes, or by a mantle of weathered lava and scattered boulders. Small springs and seeps are commonly associated with the landslide debris. However, the storage capacity of this material is quite limited and is of minor importance in supplying usable quantities of ground water.

14. Sediments of the Cache formation are composed of beds of angular gravel and silt. The low sand content accounts for the low overall permeability of the unit.

15. Stream channels such as Dry Creek in Collayomi Valley are composed of loose sand and gravel and allow ground water recharge from stream flow. Deposits such as these, where buried, will provide abundant quantities of ground water to wells.

Water-Yielding Capacities of Alluvial Materials

Because the alluvium, with few exceptions, is the only important water-bearing unit in the Upper Putah Creek Basin, its water-yielding properties should be considered in detail. One indication of the ground water potential of the alluvium is its average specific yield. Specific yield is the ratio of the volume of water which a saturated material will yield by gravity to its total volume. Fine-grained materials such as clay and silt have a lower specific yield than coarser materials such as sand and gravel. The specific yield of the water-bearing materials in the Upper Putah Creek Basin was estimated from analysis of existing well drillers' logs. All basin sediments were divided into five general catagories. Table 18 contains a summary of specific yield values assigned to each category.

Maximum theoretical quantities of extractable water, or storage capacity may be developed from these values of specific yield. This was done by taking the weighted average of all of the unit specific yields and multiplying by the total volume of sediments in the valley. Table 19 presents the average specific yield and estimated ground water storage capacity for each of the major valleys.

TABLE 18

ASSIGNED VALUES OF SPECIFIC YIELD OF MATERIALS
PENETRATED BY WELLS
IN UPPER PUTAH CREEK BASIN

Assigned specific yield, in percent	Description of typical materials encountered in wells
3	Clayey soil, mud, clay, hardpan, tightly cemented gravel and clay, fractured bedrock, and related fine-grained deposits.
5	Conglomerate, sandy clay, cemented sand, loam, cemented gravel and boulders, and related deposits.
10	Silty sand, fine sand and gravel, dirty gravel, interbedded clay and gravel, and related deposits.
20	Sand.
25	Sand and gravel, coarse gravel, boulders and gravel, and boulders.

TABLE 19

ESTIMATED AVERAGE SPECIFIC YIELD AND GROUND WATER
STORAGE CAPACITY OF SELECTED VALLEY FILL AREAS IN
UPPER PUTAH CREEK BASIN

Valley	Average specific yield, in percent	Estimated ground water storage capacity, in acre-feet
Collayomi	6.5)	37,000
Long	4.5)	
Coyote	10.0	27,000*
Pope	3.0	7,000
Capell	3.0	700

* Storage capacity of depth interval from 10 to 100 feet. Total depth of alluvium is not known.

Movement, Replenishment, and Depletion of Ground Water

The rate of ground water movement in a water-bearing material is governed by its permeability and its differential head. The permeability of a material is its capacity for transmitting water under a prescribed differential head. This factor may limit the yield obtainable from wells and the recharge from percolation of surface waters. In stream deposited sediments, interbedded with clays and silts of lake deposits, it is not uncommon for sediments to have a very low permeability in the vertical direction and a relatively high permeability in the horizontal direction. The low permeability in the vertical direction tends to greatly inhibit natural recharge from percolating surface waters, but the effect of this phenomenon on the yield of wells can usually be offset by perforating the well casing in each of the water bearing strata or by gravel-packing the wells and thereby interconnecting the many lenses of water bearing strata.

In general, the direction of ground water movement in the Upper Putah Creek Basin approximates that of surface drainage, but in certain instances it may have been naturally altered by the geology of the area. The direction of ground water movement is also influenced by topographic conditions, sources of replenishment, and areas of extractions.

The major natural sources of ground water replenishment in the Upper Putah Creek Basin are infiltration and percolation of surface streams, and deep penetration of precipitation. In some areas, relatively small amounts of ground water recharge result from deep penetration of irrigation return flow and septic tank effluent.

Depletion of ground water also occurs by both natural and man-made causes. Natural causes include effluent discharge into streams and springs, evapo-transpiration by phreatophytes, and evaporation in areas of a shallow water table. Depletion by man-made causes occur principally from ground water extractions by pumping from wells or sumps and through development of spring flow.

The yield of wells in the Upper Putah Creek Basin varies over wide limits depending on geologic and hydrologic factors. In general, wells penetrating fractures and joints of the older rocks of the Upper Putah Creek Basin have very low yields, incapable of furnishing water in sufficient quantities for irrigation purposes. The highest yields are generally obtained from wells in the Recent alluvial deposits, where yields of up to 1,160 gallons per minute and specific capacities up to 59 gallons per minute per foot of drawdown have been reported. However, due to a predominance of fine-grained materials in many localities, some wells drawing from alluvium produce only very limited quantities of water.

Principal Ground Water Basins

The term ground water basin (or ground water reservoir) is used to denote areas where ground water is accumulated under conditions that make it suitable for development and use. A ground water basin is usually bounded by relatively impermeable rocks, faulting, or other geologic structure or condition that impedes ground water movement. If no known subsurface boundary is present, a topographic divide, or constriction in the water bearing material may also set the limits of a basin.

In some cases a ground water basin may include areas of slight to moderate relief, or may include portions of fairly mountainous topography.

Of the numerous small alluvial filled valley areas scattered throughout the Upper Putah Creek Basin and containing some ground water, only the four most important are discussed in detail in this bulletin. Of these Pope and Capell Valleys contain only a few pockets of water bearing materials and generally have small yields. This condition may permit slight development of these valleys but the lack of ground water readily available in quantity will be a handicap. The conditions giving rise to the situation are discussed in greater detail later in this bulletin. The locations of the various valleys and ground water basins in the Upper Putah Creek Basin are shown on Plate 3.

Collayomi-Long Valleys Ground Water Basin

Collayomi-Long Valleys Ground Water Basin, located in the headwater area of Putah Creek, comprises a surface area of about 8,500 acres. The two valley areas, Collayomi and Long, are considered as one ground water basin because of their hydraulic and hydrologic continuity. It is the most extensively developed basin in the Upper Putah Creek drainage. Middletown, the largest community in the Upper Putah Creek watershed, lies in the central portion of the basin. Both Collayomi and Long Valleys contain extensive valley floor areas which are interconnected. The boundary line of the ground water basin coincides with the edge of the valley floor areas except where water-bearing landslide debris and

Quarternary basalt extend from beneath the valley floor into the uplands. Upland areas composed of the latter two materials, were included in the general outline of the basin, but due to lack of data no storage estimates of these areas were made.

Geology. The geologic history of the Collayomi-Long Valleys area is long and complex. During the Mesozoic and early Cenozoic eras the area was part of a region which was inundated repeatedly by marine seas. Great thicknesses of sediments were then deposited, lithified, deformed, faulted, and locally intruded. During the late Cenozoic era large portions of the area were blanketed by volcanic rocks. Today the Collayomi-Long Valleys area is underlain by complexly folded and faulted sedimentary rocks which are capped locally by volcanic rocks.

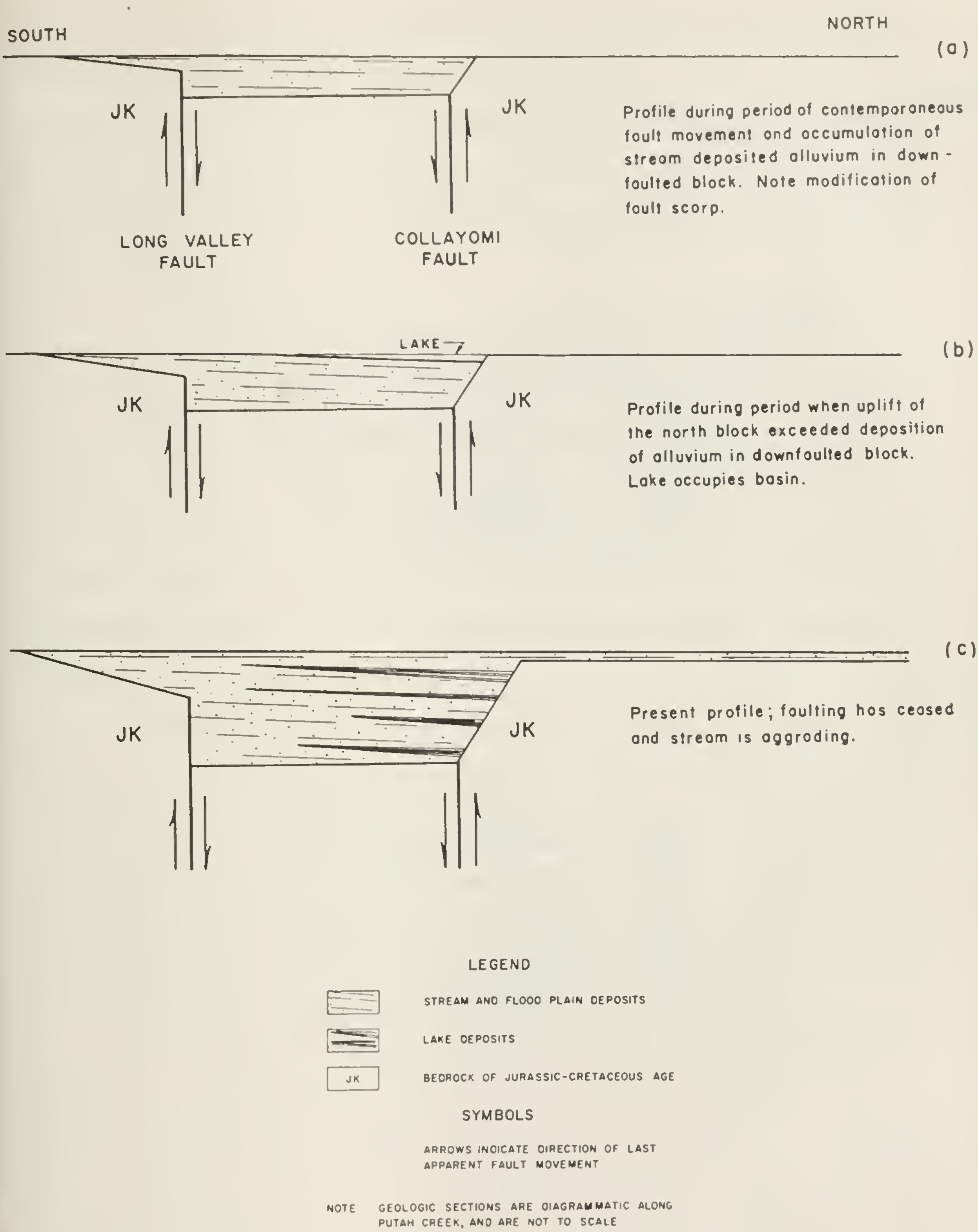
Stream drainage patterns developed over a long period of time, and eventually the ancestral courses of what are now Putah, Dry, and St. Helena Creeks were established. Since the area was being subjected to strong deformation these stream courses were often modified. Upson and Kunkel (Ref. 37) have suggested that Putah Creek may have originally flowed through Long Valley and Bucksnort Creek. This theory could explain the development of Long Valley which at present is not drained by a perennial stream. However, at some other time in the past, due to faulting or local uplift at the eastern end of Long Valley, diversion of Putah Creek to its present course occurred.

Two important geologic features which have a direct bearing on drainage development of the area are the Collayomi fault and the Long Valley fault (see Plate 4). These faults, along with a small north-south fault at the southeastern end of Long Valley, bound a pie-shaped down-tilted block which forms the deep basin at the confluence of Long and Collayomi Valleys. This tilted block is about 7 miles long and 1.5 miles wide at the southeastern end in Long Valley. It would appear that the downward movement of the fault block was greater near Putah Creek than at the southern end of Long Valley. The Collayomi fault is readily identifiable, strikes N67°W, and dips nearly vertically. Based on drainage offset, the Collayomi fault has an apparent surface displacement of about one mile. The fault has been traced definitely for about 12 miles from Whispering Pines through Butts Canyon, and may extend much further to the southeast. The Long Valley fault begins in Collayomi Valley where it appears to branch off the Collayomi fault. It continues southerly, striking N50°W and dipping nearly vertically, into Pope Valley, where it may bound the northeast side.

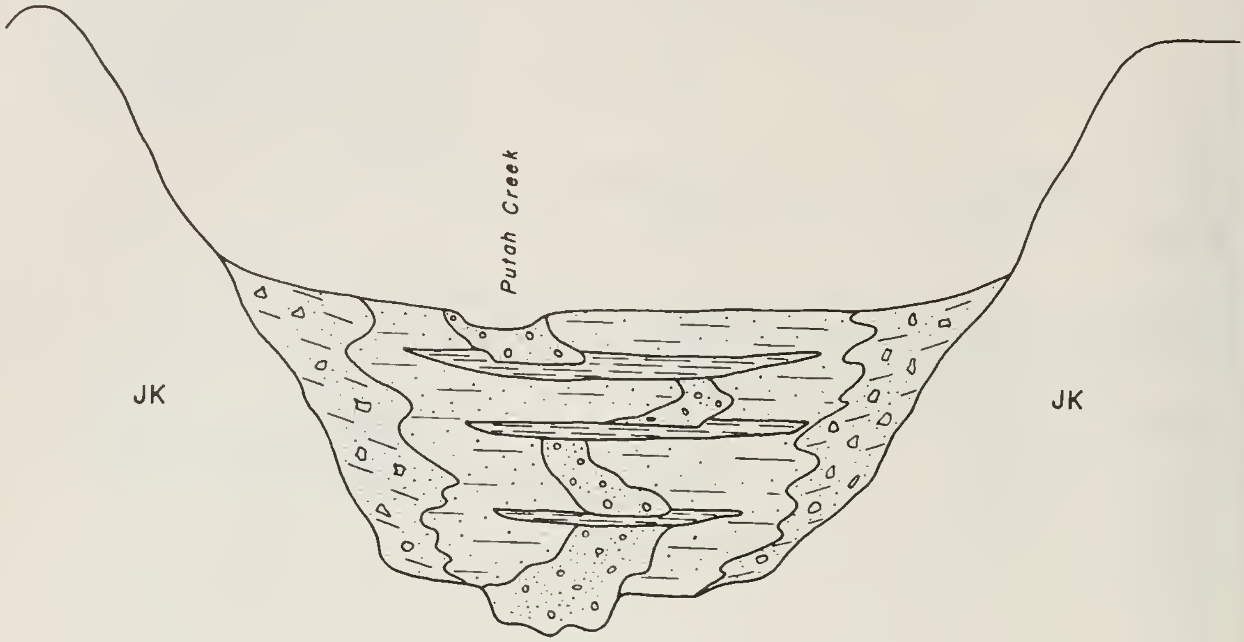
The Collayomi and Long Valley faults appear to control the composition and thickness of the alluvium in Collayomi and Long Valleys and also along Putah Creek downstream from the ground water basin. Well 11N/7W-33L2, located in Collayomi Valley at a surface elevation of 1,100 feet, intersected the alluvium-bedrock contact at a depth of 444 feet, elevation 656 feet. In the canyon of Putah Creek below the Collayomi and Long Valleys at surface elevation 1,040 feet, the estimated depth of alluvium is only about 40 feet, with the alluvium-bedrock contact being at elevation 1,000 feet. Thus, it appears that bedrock in Collayomi Valley is about 350 feet lower in elevation than bedrock in Putah Creek Canyon, downstream from the ground water basin. Bedrock crops out at the southeastern end of Long Valley, at elevation 1,130 feet. This indicates that the bedrock surface has a rise of about 475 feet in the $4\frac{1}{2}$ miles traversed from well 11N/7W-33L2 to Putah Creek Canyon.

These incongruities in bedrock elevation may most logically be explained by contemporaneous faulting and deposition (as shown on Figure 7). It would appear that the block between the Collayomi fault and the Long Valley fault, including part of Collayomi Valley and nearly all of Long Valley, underwent a downward displacement with respect to the areas north and south of it. As this faulting occurred, Putah Creek continued to flow along its course and maintained grade by eroding the block north of the Collayomi fault and depositing its load in the downfaulted area. If, during this period of time, the uplift along the Collayomi fault exceeded the capacity of the stream to erode through the uplifted block, a lake was probably formed (see Figure 7 (b)). The lithology in the basin was thus controlled by the environmental conditions in the valley. Coarse-grained stream gravels and sands with associated finer-grained flood plain deposits accumulated during times when the valley was occupied by a stream, and silt and clay predominated whenever the basin was occupied by a lake.

The stream deposited material of the Recent alluvium is generally the most important water-bearing unit of the basin. The lithologic character of the alluvium is directly controlled by the drainage development and structural history of the area. Assuming the hypothesis concerning the Collayomi fault to be correct, Collayomi and Long Valleys have been subjected to periods of inundation. While the valleys were flooded,



DIAGRAMMATIC SKETCH SHOWING
HYPOTHETICAL EVOLUTION OF COLLAYOMI-LONG VALLEYS
GROUND WATER BASIN



LEGEND

- **STREAM DEPOSITS** — COARSE-GRAINED MATERIALS, GOOD PERMEABILITY
- **LAKE DEPOSITS** — FINE-GRAINED MATERIAL, LOW PERMEABILITY
- **FLOOD PLAIN** — MEDIUM-FINE-GRAINED MATERIAL, LOW PERMEABILITY
- **SLOPEWASH** — COARSE-TO FINE-GRAINED MATERIAL, POORLY SORTED, GENERALLY LOW PERMEABILITY
- **JK — JURASSIC-CRETACEOUS** — BEDROCK, IMPERMEABLE

NOTE: GEOLOGIC SECTION NOT TO SCALE.

DIAGRAMMATIC GEOLOGIC SECTION OF STRATIFIED MATERIALS IN THE COLLAYOMI-LONG VALLEYS GROUND WATER BASIN

fine-grained lacustrine materials were deposited in the valley. Once erosion cut through the barrier at the mouth of the valley, typical stream laid gravels and sands were deposited along with the associated fine-grained flood plain materials. It appears that at any given time the coarse-grained materials occupied only a small portion of the valleys. This is illustrated in Figure 8.

In general the stream deposits are gravels, sands, and associated silts. These sediments generally are the most permeable units in the basin and may reach a maximum depth of over 400 feet. In contrast, the fine-grained sands and silts deposited on the flood plain have low permeabilities. The lowest permeabilities of all are found in the lacustrine deposits. These appear to be the blue clays so often reported in the well drillers' logs. The deeper lacustrine deposits are believed to belong to the Cache formation.

Numerous areas of landslide debris consisting of slumped rocks and talus, generally associated with serpentine and Franciscan rocks, surround Long Valley and Collayomi Valley. The accumulations consist of an unconsolidated and unstable mixture of rock and soil. The unit is locally permeable; however, its limited areal extent precludes it from being of importance as an aquifer in the ground water basin.

The Quaternary basalt crops out locally both north and east of Middletown. The log of well 11N/7W-34J2, indicates the presence of a ledge of hard gray rock, presumed to be basalt, from depths of 72 to 85 feet. From the log of this well, it appears that the basalt may extend across the valley as a flow interbedded with lacustrine sediments of the Cache formation. In outcrop, the basalt is fractured and broken and should have good overall permeability. Thus, when situated beneath the water table, it may be capable of yielding good quantities of water.

In general, the sedimentary, landslide, and volcanic water-bearing deposits are flanked and underlain by materials of the Franciscan-Knoxville groups consisting of marine deposited graywacke, shale, and associated rocks which are locally intruded by serpentine. These rocks are generally considered to be nonwater-bearing although in some areas joints, faults, and shear zones probably contain some water.

Hydrology. Ground waters throughout the Collayomi-Long Valleys basin are not stored in a single mass of homogeneous sediments with unrestricted lateral and vertical movement, but occur in a series of confined, semiconfined, and unconfined layers, compartments, and lenses of permeable or semipermeable materials which are partially merged and interconnected. There is no evidence of any well defined aquifer of great areal extent within the basin. The phenomenon of confinement is evidenced from several well drillers' logs which show the level where water was first encountered to be below the standing water level in the well after completion.

The total volume of saturated valley fill material is estimated to be 400,000 and 240,000 acre-feet in Collayomi and Long Valleys, respectively. Analysis of well logs indicates that the valley fill materials range in specific yield from 3 percent for clays to 25 percent for gravels. The overall average values are 6.5 and 4.5 percent in Collayomi and Long Valleys, respectively. From this it is indicated that the gross ground water storage capacity in the Collayomi-Long Valleys Basin is about 37,000 acre-feet. Not all of this storage capacity is usable, however, because of practical considerations of basin operation.

A few periodic records of water level measurements in wells are available for the period beginning with the early 1950's. These measurements indicate that water levels in the basin are drawn down by pumping during summer months and that the basin fills up each year during the winter and spring months. While these measurements are insufficient to determine ground water flow pattern it is believed that ground water movement, in general, follows the same direction as surface drainage.

Measurements of water levels in about 53 wells were made in Collayomi-Long Valleys in the fall of 1960 and the spring of 1961. To accurately determine the pattern of ground water flow from these measurements it would be necessary to first determine the reference point elevations by field survey. This was not done due to a limitation of time and funds. However, on the basis of the water level measurements, the average rise in ground water levels throughout the basin for this period was estimated to be about eight feet. This rise of water levels was estimated to represent a change in storage of from 3,000 to 4,000 acre-feet, or about 8 to 11 percent of the estimated total quantity of water stored in the basin.

The major source of recharge to the Collayomi-Long Valleys Basin is from percolation of stream flow in Putah, Dry, and St. Helena Creeks, although some recharge is derived from deep penetration of rainfall and irrigation return flows. These streams comprise about 80 percent of the 40 square mile drainage area tributary to the basin and produce an estimated mean annual runoff of about 64,500 acre-feet. The estimated mean annual runoff from all sources tributary to the basin and the estimated mean annual precipitation on the basin are 73,000 acre-feet and 31,500 acre-feet, respectively. Historically, recharge has been retarded by full basin conditions. Only minor quantities of surface stream flow is available for recharge in the Long Valley portion of the basin and this may be impeded to an unknown areal extent by hardpan conditions near the ground surface. However, it is believed that some recharge to the Long Valley portion of the basin may be derived in the form of subsurface flow from the area of Quaternary basalt on the south and from the alluvium at the lower end of Collayomi Valley.

Present Ground Water Development. Early development of ground water in the Collayomi-Long Valleys Basin was principally confined to dug and drilled domestic wells, although small amounts of water were pumped for irrigation. Since about 1950, a few irrigation wells have been developed; these are primarily confined to the Collayomi Valley portion of the basin. It is estimated that there have been over 150 wells drilled in the basin, of which about 100 were located during the well canvass conducted as part of this investigation. Irrigation was classified as the major use in only 16 of the wells visited. Active irrigation wells are reported to yield from 20 to 725 gallons per minute, with specific capacities ranging from 0.2 to 59. For the most part, active wells in Long Valley are limited to domestic and stock watering purposes. One notable exception is well number 10N/7W-1C1 located on the Reed Ranch in the northwesterly portion of Long Valley. Although this well has not been used on a production basis, the results of pump tests indicate that it is capable of supplying over 1,000 gallons per minute.

More than 50 percent of the 900 acres of land presently irrigated throughout the basin is served wholly or in part from ground water. Although Middletown does not have a public water system, it is supplied from private domestic wells which often serve several dwellings. Some of the shallow wells in town go dry in summer months, and, in such cases, water is generally obtained from a deeper neighboring well.

Potential for Increased Ground Water Development. It appears that there is some potential for increased ground water development in this basin. The total ground water storage capacity of the Collayomi-Long Valleys Basin was estimated to be about 37,000 acre-feet, and the maximum ground water storage depletion under present conditions of development was estimated to be as much as 4,000 acre-feet. Thus, with present pumping patterns, only about 11 percent of the total available storage capacity is being utilized. It also appears that increased salvage of water wasting from the basin can be effected by increased extraction and use of ground water with a resultant lowering of the water table during dry periods and increased replenishment during ensuing wet periods. Accurate estimates of the extent of further development of ground water supplies from this basin could not be determined from available data. Instantaneous stream flow measurements made in November, 1960 at various points on Putah, Dry, and St. Helena Creeks indicated that all

16. A young orchard in Collayomi Valley. Water supply for this area is derived from alluvial contained ground water. (Note well houses center and right background.)

17. Putah Creek near Middletown. Percolation from stream flow to ground water occurs primarily in such stream gravels.

surface stream flow entering the basin, up to a total of 14 second-feet, would infiltrate into the channel gravels of these streams under natural conditions. It is probable that these waters would percolate to ground water. On the assumption that infiltration and percolation are a function of wetted area, and that wetted area is a function of stream flow, it was estimated, using the natural regimen of stream flow, that the mean annual percolation from these streams could approach 9,000 acre-feet, provided ample storage space were made available and percolation was not impeded by a high water table. This amount represents only about 12 percent of the total surface supply entering the basin and is assumed to represent the upper limit of development from this basin unless artificial recharge methods were used. Whether or not this amount could actually be developed would depend on several factors.

The principal factor is the transmissibility of basin materials. This factor controls the yield of wells and the lateral movement of percolating water from the stream channels. Even though the effect of this factor could not be determined during this reconnaissance investigation, it is not unreasonable to assume that the estimated present rate of ground water extraction could be doubled if the pumping were concentrated in the most pervious materials located in the central portion of the basin near the vicinity of the confluence of Putah, Dry and St. Helena Creeks. Although increased extractions could probably be accomplished in other portions of the basin, the probability of obtaining good irrigation wells appears to be less. Under such a plan of basin operation, distribution of pumped waters would have to be conveyed from the centralized location of the well field to other portions of the basin.

From a practical standpoint, however, there are legal considerations which must be recognized in any plan for operation of ground water storage. Under the law, an owner of land overlying a ground water basin has a paramount right, correlative with all other overlying landowners, to the reasonable beneficial use of ground water in the basin. The landowner, therefore, is entitled to the protection of the law against any substantial infringement of his correlative right to ground water which he reasonably requires for beneficial use, and against any use of ground water by an appropriator which would cause impairment to his right. Increased use and changes in pumping pattern would result in a lowering of ground water levels. However, the attendant inconvenience or extra expense to an overlying landowner would not necessarily prevent such planned operation, providing it could be shown that such inconvenience or added expense were not unreasonable.

The question of what constitutes unreasonable inconvenience or expense is not subject to exact determination. However, it might be assumed that greater energy costs resulting from increased pumping lifts would not be considered unreasonable as long as presently installed pumping equipment of the overlying landowner could continue to be utilized. A material lowering of ground water levels that would necessitate deepening of wells and/or replacement of pumping equipment might be considered unreasonable. In practice, these matters would have to be determined by negotiated agreement or by the courts. The success of planned operations of the Collayomi-Long Valleys ground water basin by a centralized well field would be contingent upon the negotiation of a mutually satisfactory agreement between the overlying ground water users and the operating agency of the centralized well field.

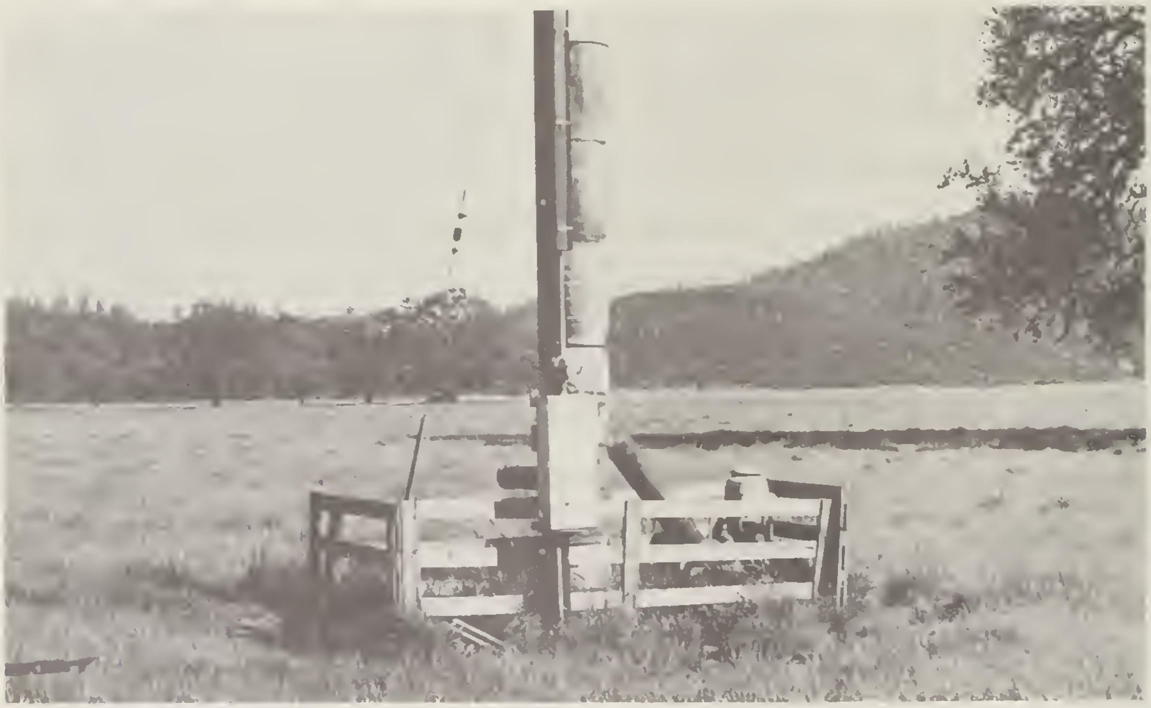
Coyote Valley Ground Water Basin

The Coyote Valley ground water basin is located on Putah Creek downstream from Collayomi Valley (see Plate 3). It is the northernmost ground water basin in the Upper Putah Creek Basin and has a surface area of about 10,000 acres, of which about 6,000 acres are underlain by basalt of the Clear Lake volcanics and sediments of the Cache formation. The boundary line of the ground water basin coincides with the edge of the valley floor except along the northeastern side where volcanic rocks and continental sedimentary rocks extend from beneath the valley floor into the uplands. The upland area, forming the northeastern part of Coyote Valley basin, was included within the basin but was not considered in ground water storage computations.

Geology. The geologic history of Coyote Valley is similar to that of the Collayomi-Long Valley Basin. During the Mesozoic and early Cenozoic eras the valley was part of an area which was inundated repeatedly by marine seas. Great thickness of sediments were deposited, lithified, deformed, faulted, and locally intruded. By late Cenozoic time the area was eroded into a fairly deep stream-cut valley. The ancestral course of Putah Creek probably flowed through the valley following a course somewhat parallel to its present course.

Then, in late Cenozoic time, the lower portion of the valley was inundated by a fresh-water lake and continental sediments now belonging to the Cache formation were deposited. This was followed by

18. Alluvium in Long Valley contains a zone of claypan at shallow depth. This condition inhibits ground water recharge, limits soil depth, and restricts agricultural development to shallow rooted crops. It may cause ponding of surface water and extensive drainage problems under full irrigation development.



19. A well in Coyote Valley. This well is 110 feet in depth and, when drilled in 1951, had a reported yield of 1,000 gallons/minute with a 17-foot drawdown.

volcanism from eruptive centers immediately northeast of Coyote Valley. Outpourings of basaltic lava flowed from these volcanic vents and formed a northwest trending ridge across the downstream end of the ancestral Coyote Valley. Subsequent faulting along the Childers Peak fault has resulted in the uplift of the valley with respect to the ridge to the northeast. As a result of these events, the course of Putah Creek through Coyote Valley, and the configuration of Coyote Valley itself, have been greatly modified with time.

Knowledge of the thickness of alluvial material in Coyote Valley is meager. Well log and pump test data are scarce. None of the wells with available logs have penetrated completely through the valley fill. Based on surficial geologic observations and the four well logs available, it appears that the fill in Coyote Valley may be up to 300 feet in thickness. Apparently, much of the basin is filled by the continental sediments of the Cache formation. Judging from the isolated patches of basalt which occur in the valley, it is possible that the basalt may underlie extensive portions of the basin, at least locally. Recent alluvium appears to occur as a veneer over the Cache formation and fill deep, buried channels.

The Recent alluvium, as is the case in the other basins, is the most important water-bearing unit of the basin. The alluvium appears to consist of poorly stratified sand, gravel, and fines. Sandy and silty gravels appear to be the best water-bearing materials in the alluvium. The gravels occur in sheets and stringers between beds of silty clay and sandy clay. The gravels probably represent stream channel deposits while the finer sediments were probably deposited on ancient flood plains of Putah Creek.

The Cache formation crops out along the northeastern edge of Coyote Valley, locally in the valley, and probably underlies much of the valley. The formation is composed of gravel, silt, and tuffaceous sand with some pebbly limestone and diatomite being reported locally. The dominant constituent of the Cache beds is a light gray silt. Beds of coarse unsorted pebbles and cobbles occur locally, but these generally have a silty matrix. Generally, the amount of fines present in the Cache beds render the unit relatively impermeable. However, occasional beds of gravel or sandy gravel having high permeabilities may occur. These beds, by the nature of their occurrence, are considered to contain confined water. Well No. 11N/6W-20D5, near Gallagher Creek, may be producing from one or several of these confined beds. It was reported by the driller that the well is 140 feet deep and is perforated from 100 to 140 feet. The depth to static water level varies from about 6 to 15 feet. Thus, it appears that water in this well is under about 80 or 90 feet of head.

Quaternary basalt overlies the Cache beds in and northeast of the valley. The basalt occurs as a series of lava flows which are fractured locally. When situated below the water table, the basalt may yield some water. However, it is particularly notable for accepting recharge for the ground water basin.

The alluvium, basalt, and Cache sediments are flanked and underlain by sediments of the Franciscan-Knoxville groups, serpentine, undifferentiated Cretaceous rocks, and possibly by the Martinez formation. These rocks are mostly nonwater-bearing although locally, joints, faults, and shear zones probably contain some water.

Hydrology. Ground water in the Coyote Valley Basin is found in the Cache formation and in the Recent alluvial deposits which were laid down along the old stream channels of Putah Creek. Due to the type of deposition in both the Cache formation and the alluvium, ground water is not stored in one layer of homogeneous sediments but occurs in a series of sand and gravel lenses separated by silt and clay. There is no evidence of any well defined aquifer of any great areal extent in the basin.

Due to the lack of well logs in the area, no accurate estimate of the storage capacity could be made. In 1952, the U. S. Geological Survey estimated in Water Supply Paper 1297 (Ref. 37) that the storage capacity of the depth interval from 10 to 100 feet of the alluvium beneath the valley floor is at least 27,000 acre-feet. This was based on an assumed specific yield of 10 percent. Wells drilled in the basin since that time tend to substantiate this assumption of a relatively high specific yield. Since the depth of the alluvial deposits in Coyote Valley has not been ascertained, it is impossible to estimate the total storage capacity of the basin.

A few periodic water level measurements in wells have been made in the last few years. These measurements indicate that water levels are drawn down by pumping during the summer months and then recover each year during the winter months. These measurements are not sufficient in number to determine ground water flow pattern, but it is believed that when the basin is full the movement follows the same general direction as the surface drainage. Localized dewatering by pumping may cause the movement to deviate from the general direction of surface drainage to such an extent that the wells in the vicinity of Crazy Creek and Gamble Road may be drawing some of their ground water from the vicinity of Putah Creek.

Measurements of water levels in 20 wells in Coyote Valley were made in the fall of 1960 and the spring of 1961. The average rise in water levels for this period was estimated to be about six feet. This rise of water levels was estimated to represent a change in storage of about 4,000 acre-feet.

The major source of recharge to the area appears to be from percolation of stream flow in Putah Creek, with lesser amounts percolating from Coyote and Crazy Creeks. The estimated mean annual inflow to Coyote Valley from Putah Creek is 124,000 acre-feet. An additional 10,000 acre-feet is received from all sources tributary to the basin. The mean annual precipitation on the valley floor and the upland volcanic portions of the basin is estimated to be 35,000 acre-feet. The combined mean annual inflow and precipitation is 169,000 acre-feet.

Present Ground Water Development. Early development of ground water in Coyote Valley Basin was principally confined to dug and drilled domestic wells to serve the few farm houses scattered throughout the valley. In recent years from 7 to 8 irrigation wells have been drilled. The yields on these wells range from about 100 to 1000 gallons per minute, with specific capacities from 5 to 195 gallons per minute per foot of drawdown. In addition to these irrigation wells some farmers pump from sumps along Putah Creek. This latter source of supply is dependent upon the continual recharge into the basin by Putah Creek. If the recharge is prevented by excessive pumping upstream the water table in the lower end of the valley drops below the bottom of the sumps and they dry up. The water from the sumps and irrigation wells is used to irrigate an estimated 400 acres of agricultural land in Coyote Valley.

Potential for Increased Ground Water Development. It appears that there is a good potential for increased ground water development in this basin. The storage capacity of the alluvium between the depths of 10 and 100 feet has been estimated to be approximately 27,000 acre-feet, while the maximum ground water storage depletion under present conditions of development was estimated to be 4,000 acre-feet, or about 15 percent of the computed storage capacity in the 10 to 100 foot zone. The total thickness of the alluvium has not been explored. Well 11N/6W-20D5, located near the edge of the valley at Gallagher Creek, apparently penetrates a confined aquifer in the Cache formation. It is possible that the Cache formation may extend under the recent alluvium in the valley. Although much of the Cache formation is relatively impermeable, similar water producing confined aquifers may occur at depth in other parts of the valley.

The area along the northeast side of the basin, bordering the outcrop of the Cache formation, is relatively tight. With the exception of well 11N/6W-20D5 there have been no high producing irrigation wells drilled in this area. The best area of potential well development appears to be limited to that portion of Coyote Valley which extends along the south side of Putah Creek from the Highway 53 Bridge southwesterly to Crazy Creek.

Instantaneous stream flow measurements made in November 1960, at various points on Putah and Coyote Creeks, indicated that all surface stream flow entering the basin up to a total of 9 second-feet would infiltrate into the channel gravels of these streams under natural conditions. On the assumption that infiltration and percolation are a function of wetted area, and that wetted area is a function of stream flow, it was estimated, using the natural regimen of stream flow, that the mean annual percolation from these streams could approach 9,300 acre-feet, provided ample storage space were made available and percolation was not impeded by a high water table. This amount represents only about 7 percent of the total inflow to the valley and is assumed to be the upper limit of development from the basin unless artificial recharge methods were used.

It is impossible to determine at the present time the amount of potential development available. This amount depends primarily upon transmissibility of the alluvium and the Cache materials. This factor not only controls the yield of wells but also the lateral movement of percolating water from the recharge areas. Even though the effect of this factor could not be determined, it is not unreasonable to assume that the estimated present rate of ground water extraction could be tripled if the pumping were concentrated in the central portion of the basin. Increased extractions could probably be accomplished in other portions of the basin, but the probability of obtaining a good irrigation well in the fringe areas is much less. The development of a centralized well field would require the distribution of its pumped water to other portions of the basin near its periphery. The legal considerations involved in such an operation have already been discussed in the preceding section on Collayomi-Long Valley Basin.

Pope Valley

Pope Valley is located about six miles west of the northerly portion of Lake Berryessa (see Plate 3). The valley is drained by Pope Creek, and its principal tributary, Maxwell Creek. Ground water occurs in the alluvium and in several areas of pervious volcanic rocks near Aetna Springs. The areal extent of the water-bearing rocks in Pope Valley is about 9,300 acres. The boundary between the water-bearing and nonwater-bearing materials roughly coincides with the edge of the valley floor, except for a few acres of upland volcanic rocks near Aetna Springs.

Geology. The bedrock which underlies Pope Valley represents the same sequence of Mesozoic marine sedimentary and volcanic rocks which occur elsewhere in the Upper Putah Creek Basin. Pope Valley lies in an area which was inundated repeatedly by marine seas during Jurassic and Cretaceous time. Tremendous thickness of sediments were deposited, lithified, faulted, deformed, and locally intruded by serpentine and associated rocks. During the Cenozoic era, the area was uplifted and eroded and Pope Valley developed into a rather broad area of undulating land surrounded by higher ridges. Apparently, throughout the history of the valley, stream development has been limited to small creeks. Thus, Pope Valley has developed primarily as a structural basin rather an erosional basin.

The fact that Pope Valley was structurally formed is important in that great thicknesses of alluvium generally associated with large streams did not accumulate. In fact, based on the few, scattered well logs available, it appears that the alluvium may average only about 25 to 30 feet in thickness. Since large stream flows are lacking, the alluvium consists chiefly of silty and clayey sands and gravels. Geologic inference indicates that clean sand and gravel lenses may occur, although none have been observed. Although the alluvium is tight it yields limited quantities of water.

Several small outcrops of Sonoma volcanic rocks occur near Aetna Springs. These rocks, generally considered as water-bearing, are of such a local nature and so isolated that whatever extractable ground water they contain is not of significant quantity.

The remainder of the basin is underlain by marine sandstones and shales of Jurassic-Cretaceous age, and by Jurassic serpentine. Connate water could be encountered locally in the marine sediments. Several deep wells have penetrated these rocks, but with only one exception, they have not encountered significant quantities of water. These rocks are considered as nonwater-bearing although some water may be found along fault and shear zones.

Hydrology. Ground water in Pope Valley is found in limited quantities in the shallow alluvium and along fault and shear zones in the underlying marine sandstones and shales. Due to lack of well logs in the area, no accurate estimate of the storage capacity could be made. A rough estimate can be made by assuming an average thickness of alluvium of 25 feet and an average specific yield of 3 percent. Using these assumptions the storage capacity of the alluvium would be about 7,000 acre-feet. Most of the alluvial material is relatively thin, patchy, and impermeable, making it uneconomical to utilize this storage capacity through pumping.

A few periodic water level measurements in wells were made in 1954-55 and 1960-61. These measurements show that water levels are drawn down by pumping and natural causes during summer months and recover each year during the winter and spring months. The average recovery in 26 wells from fall 1960 to spring 1961 was about 9 feet. These measurements are not sufficient to determine ground water flow pattern, but it is believed that when ground water levels are high movement is toward the creeks.

It is believed that the major source of recharge to the area is from infiltration of winter precipitation, with the exception of small isolated areas adjacent to surface gravel deposits along portions of Pope and Maxwell Creeks. A series of instantaneous stream flow measurements were made at various points along Pope, Burton, Hardin and Maxwell Creeks following the first storm of the season in November 1960. This series of measurements indicated that very little water (about 3.5 cfs) was percolating into the alluvium from the stream flow. Following the second storm of the season, the alluvium was yielding water to the streams.

Present Ground Water Development. Early development of ground water in Pope Valley was limited principally to dug and drilled domestic wells to serve the few farms and ranches scattered throughout the Valley. In recent years, several attempts have been made to develop irrigation wells. Wells more than 900 feet deep have been drilled with little success. At the present time, there is only one well in the valley, well 9N/5W-11J1, which has a reported yield of more than 100 gallons per minute.

Potential for Increased Ground Water Development. There seems to be little chance of developing wells of sufficient yield for irrigation in Pope Valley due to the limited thickness of the alluvial material and its relatively low permeability and specific yield. Future development in the valley will probably be limited to low yielding domestic wells.

Capell Valley

Capell Valley is the southernmost area in the Upper Putah Creek Basin that was investigated for ground water development. The valley is a narrow northwesterly trending depression which varies from about 500 feet to 3,300 feet in width along the valley floor. It is about 4.3 miles long with a surface area of approximately 900 acres. Capell Creek and its principal tributary, Oak Moss Creek, flow northwesterly through the valley, emptying into Lake Berryessa about 2 miles downstream.

Geology. Capell Valley appears to be a structural depression underlain by marine shale, sandstone, and related rocks of the Knoxville group of Jurassic age. The hills and ridges surrounding the valley are composed of rocks of the Knoxville group. These rocks contain occasional masses of Jurassic basalt intruded by serpentine. The ridge to the west of Capell Valley, which forms the drainage divide between the Napa River and Putah Creek, is capped by the Sonoma volcanics of Pliocene age. Recent alluvium veneers the valley floor to a shallow depth and landslide debris occurs locally on the surrounding hill slopes.

The evolution of Capell Valley has been quite complex. The presence of several large faults, which roughly bound the valley and strike parallel to it, suggest that down-faulting may have occurred. Thus, like Pope Valley, it appears that Capell Valley was formed by structural rather than erosional activities.

Apparently, stream development in Capell Valley has been of a local nature and did not result in deposition of large quantities of good water-bearing sands and gravels. The alluvium consists primarily of silt and fine-grained sand derived primarily from the weathering and erosion of the surrounding hillsides of sandstones and shales of the Knoxville group. Due to the fine-grained nature of the thin alluvium, only very limited quantities of water may be expected from wells drilled through it. In fact, based on records of the few wells located in the area, the ground water available is barely sufficient for present domestic needs.

On the west side of Capell Valley several wells have been drilled into rocks of the Knoxville group. These wells produce some potable water which appears to be coming from fractures in the bedrock. Maximum reported production in this area is about 10 or 12 gallons per minute, with a drawdown of about 100 feet. Generally, these rocks are considered to be nonwater-bearing.

Hydrology. Ground water in Capell Valley occurs in very limited quantities in the Recent alluvium and locally in fortuitously fractured Knoxville bedrock. Due to the mode of deposition and the composition of the alluvium, ground water is not stored in large extensive beds but in local sand and gravel lenses. There is no evidence of any extensive, well-defined aquifer in the basin. Due to lack of well logs in the area, an accurate estimate of the storage capacity was not attempted. However, assuming an average thickness of alluvium of 25 feet and an average specific yield of 3 percent, the storage capacity of the alluvium would be approximately 700 acre-feet. Dewatering of this small amount of storage through pumping appears to be impractical and uneconomical.

Water level measurements in a few existing wells were made in fall 1960 and spring 1961. These measurements indicate that the water levels are depressed by natural causes and pumping in the summer and fall months, and recover in the winter and spring. The average recovery in 9 wells from fall 1960 to spring 1961 was about 15 feet. These measurements are insufficient in number to determine flow patterns, but it is likely that the movement is toward Capell and Oak Moss Creeks. It is believed that the major source of recharge of the alluvium is from infiltration of winter and spring precipitation.

Present Ground Water Development. Early development of ground water in Capell Valley was limited principally to dug and drilled domestic wells to serve the few farms and ranches scattered throughout the valley. At the present time, there are no wells in the basin with a reported yield in excess of 15 gallons per minute.

Potential for Increased Ground Water Development. It appears that there is little chance of developing wells of sufficient yield for irrigation in Capell Valley. Future ground water development in the valley will probably be limited to low-yielding domestic wells.

Summary and Evaluation of Ground Water Conditions

Information on ground water within the Upper Putah Creek Basin is limited. The data collected for this reconnaissance investigation indicate that the prospects for developing additional ground water supplies throughout the major portion of the watershed are not favorable. Principal exceptions occur in Collayomi and Coyote Valleys where a substantial portion of present agricultural water requirements are met from existing wells.

In general, the various geologic units comprising the basin may be grouped into four broad categories relative to their water-bearing properties as follows: (1) the marine and intrusive rocks of Mesozoic and early Tertiary age, (2) the Tertiary continental rocks, (3) the Tertiary and Quaternary volcanic rocks, and (4) the Recent alluvium.

The marine and intrusive rocks comprise about 76 percent of the surface area of the basin, and contain relatively little extractable potable water. Locally, where jointed or faulted, they are capable of yielding small quantities of ground water sufficient for domestic and stock-watering purposes.

The Tertiary continental rocks, composed of the Cache formation and its correlatives, comprise about one percent of the surface area of the basin. They have relatively low permeabilities but are less consolidated and more permeable than the older rocks. Local lenses of clean sand and gravel may occur and be capable of yielding small to moderate quantities of water to domestic wells and springs. A well in Coyote Valley with a yield in excess of 700 gallons per minute and a specific capacity of about 9 gallons per minute per foot of drawdown, is believed to penetrate a segment of the Cache formation underlying the alluvium. Whether or not the well truly penetrates the Cache formation or if all the water is derived therefrom could not be definitely ascertained.

The Tertiary and Quaternary volcanic rocks comprise about 13 percent of the surface area of the basin. The Tertiary volcanics are generally of low permeability except locally where sandy tuff is capable of yielding fair quantities of water to wells. The Quaternary volcanics generally are capable of yielding only fair amounts of water, except in areas where highly fractured basalt occurs in the zone of saturation. In the latter case good quantities of water can be expected.

The Recent alluvium, by far the best known water producer in the basin, comprises the remaining 10 percent of the area of the basin. Production from the alluvium is quite variable and depends upon the method of deposition, composition and thickness of the sediments. Of the major valley areas studied only certain portions of Collayomi, Long, and Coyote Valleys have good possibilities for additional ground water development. Opportunity for further development in Pope and Capell Valleys is not favorable. The water-bearing characteristics of the numerous small and somewhat isolated alluvial areas, such as occur in Spanish, Snell, Paradise, and other valleys, were not studied as part of this reconnaissance investigation and no known data are available for these areas.

CHAPTER V. POSSIBLE SURFACE STORAGE PROJECTS

The quantity of water originating in the Upper Putah Creek Basin greatly exceeds all possible future beneficial uses which may reasonably be anticipated in the basin. Nevertheless, because of the intermittent character of runoff in most streams, the basin experiences natural deficiencies in water supply during the summer and fall months. Moreover, this seasonal deficiency is intensified by prolonged periods of drought. Under present conditions, direct diversions from unregulated stream flow must be curtailed during periods of low runoff. Ground water is used to lessen the deficiency in surface water supply in some localities, and surface storage is used in other areas. If the erratic runoff is to be harnessed to the needs of man sufficient storage will have to be provided to temporarily store the excess runoff of very wet periods. The question as to whether the storage capacity and regulation should be provided by surface reservoirs or ground water basins will depend upon the physical potential of ground water, and the cost of the method selected.

Previous studies have been, for the most part, limited to projects which could have been constructed as alternatives to Monticello Reservoir (Lake Berryessa), and projects that could be used in transporting water from the North Coastal Area to the major water deficient areas of California.

During this investigation, an inventory was made of possible dam and reservoir sites for local use. Sites studied during previous investigations were reviewed and evaluated with respect to their possibilities for serving local areas. Several new sites which appeared to be susceptible to local development were examined. Results of these studies are presented in this chapter.

Effect of Upstream Development on Yield of Monticello Reservoir

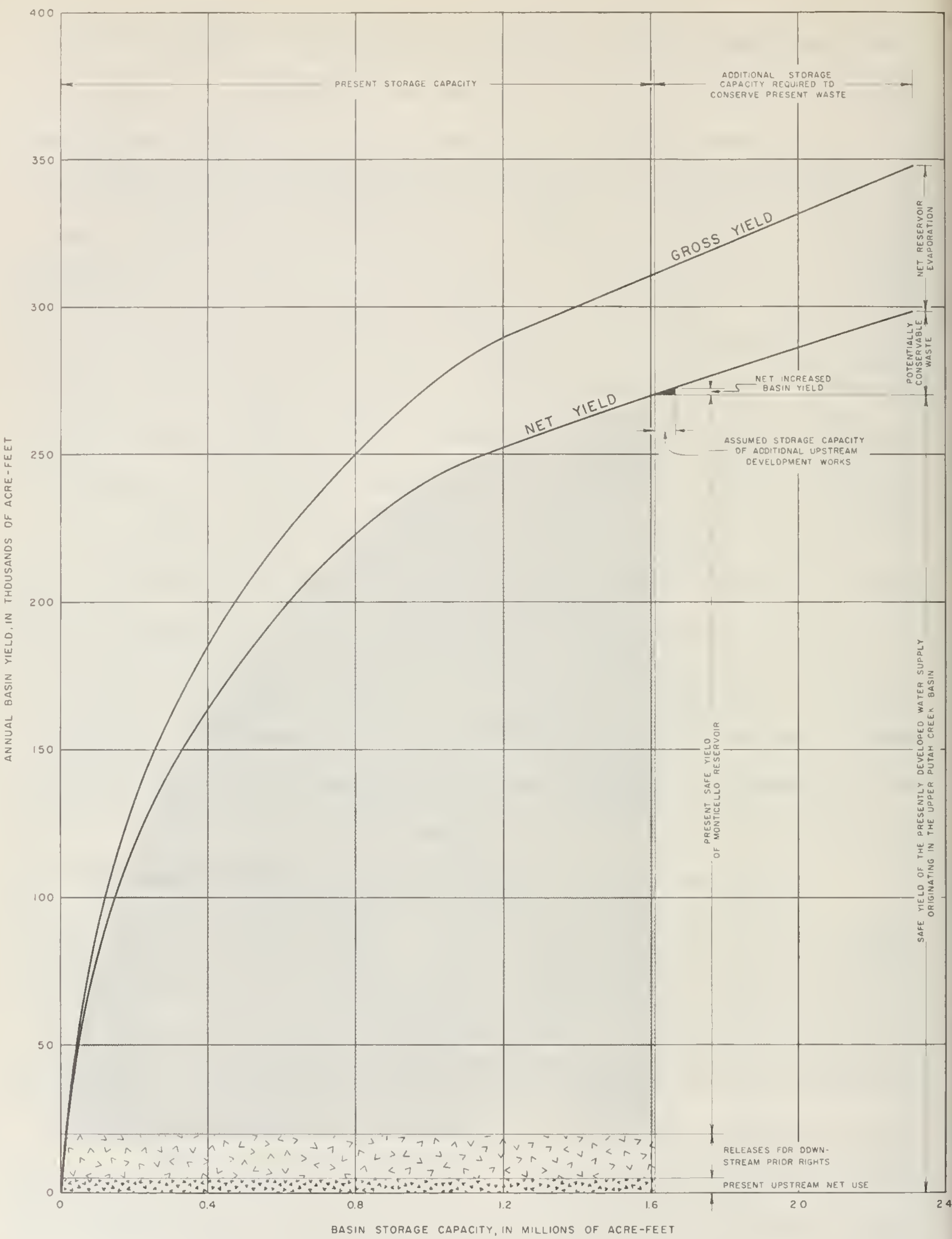
Additional upstream water development will deplete the water supply available at Monticello Reservoir. This depletion will, in turn, reduce the safe yield obtainable from Monticello Reservoir. The net reduction in Monticello yield cannot be determined directly from the amount of additional upstream storage capacity constructed nor yield derived therefrom. A combination of factors such as reservoir storage capacity, reservoir yield, reservoir evaporation, irrigation return flow, irrecoverable losses of return flow, and increased yield obtainable from the basin must be considered in making this determination. To determine the reduction it would be necessary to ascertain conditions as they would exist under a specific proposal or combination of proposals for upstream development. Since this is not possible at this time, the following hypothetical situation will demonstrate the order of magnitude and the interrelationship between these factors.

Assume that a reservoir or group of reservoirs with an aggregate storage capacity of 60,000 acre-feet are constructed in the upper basin. This amount of storage capacity could provide a safe annual yield on the order of 40,000 acre-feet, with an average annual net reservoir evaporation of about 4,000 acre-feet.

Since irrigated agriculture is the principal present and potential use of water, assume that the entire annual yield would be used for that purpose. Although in this illustration the use of the total upstream supply developed is based on irrigation use, similar conditions would exist in the case of urban and suburban uses of water.

All water applied to the land is not consumptively used in most irrigation practices. The ratio between consumptive use of applied water and the total amount of irrigation water applied varies widely between crops and among plots devoted to the same crop, depending on such factors as soil, topography, method of irrigation, drainage characteristics, and practices of the individual irrigators. For this example, assume that this ratio, called irrigation efficiency, is 70 percent. Average annual flow, that portion of the total applied water which is not consumptively used, would be 30 percent of 40,000 acre-feet or 12,000 acre-feet per year. All of this return flow would not reach Monticello Reservoir; some of it would be lost to native vegetation en route. The magnitude of this loss would be dependent on the type and extent of vegetation between the point of use and Monticello Reservoir, and the distance from the lake. For this example, it appears reasonable to assume 1/3, or 4,000 acre-feet per year of the return flow would be lost.

Additional storage capacity in the basin will increase the total amount of water conserved from the basin. This is illustrated by Figure 9. The figure depicts the approximate relationship between storage capacity and yield of the basin. It shows the present level of development and illustrates that additional storage capacity would provide a small increment of additional yield from the potentially conservable waste that exists under present development. Because of the extremely long carry-over period required, the 60,000 acre-feet of additional storage capacity would increase basin yield by only about 3,000 acre-feet per year.



EFFECT OF ADDITIONAL UPSTREAM DEVELOPMENT
ON YIELD OF UPPER PUTAH CREEK BASIN

Based on these assumptions, the net effect of the upstream development, as shown in Table 20, would be to reduce the annual yield of Monticello Reservoir by 33,000 acre-feet. It is significant to note that the net reduction of yield at Monticello Reservoir could be significantly less than either the upstream storage capacity or the reservoir yield.

TABLE 20

ILLUSTRATION OF EFFECT OF HYPOTHETICAL UPSTREAM WATER DEVELOPMENT ON YIELD OF MONTICELLO RESERVOIR

In acre-feet per year

Item	Items tending to decrease yield at Monticello Reservoir	Items tending to increase yield at Monticello Reservoir	Net reduction of yield from Monticello Reservoir due to hypothetical upstream water development
Safe yield of hypothetical upstream water development works	40,000[a]		
Net increase in basin yield from Putah Creek Basin development works		3,000[b]	
Net reservoir evaporation	4,000[a]		
Return flow of irrigation water		12,000[c]	
Irrecoverable loss of return flow	4,000[d]		
Totals	48,000	15,000	33,000

a Based on a total of about 60,000 acre-feet of storage capacity.
b Based on basin-wide storage development curve (see figure V-1).
c Based on 70 percent irrigation efficiency.
d Estimated as 1/3 of irrigation return flow.

Inventory of Possible Dam and Reservoir Sites

Investigation of possible surface storage developments in the Upper Putah Creek Basin included studies to determine amounts of water that could be developed by constructing reservoirs of various sizes at numerous sites. Surface geologic examination was made to determine suitability of each dam site for a particular type of dam and its limiting height. Reconnaissance estimates of capital and average annual costs were made for the purpose of establishing economic relationships between the various sizes of reservoirs.

Preliminary examination was made of 31 possible dam and reservoir sites, of which 12 were considered to be the more favorable ones. In addition, three stream flow diversion sites were studied to augment the yield of nearby potential storage reservoirs. Nineteen dam sites were eliminated on the basis of poor geologic or topographic conditions, limited water supply, high capital costs, excessive unit costs of water, and/or poor location. These are listed in the following tabulation. Their locations are shown on Plate 5, "Locations of Dams and Reservoir Sites".

Dam and Reservoir Sites Eliminated

Lake County		Napa County	
Dam and Reservoir	Stream	Dam and Reservoir	Stream
Upper Dry Creek	Dry Creek	Devils Head	Putah Creek
Lower Dry Creek	Dry Creek	Snell	Putah Creek
Harbin	Harbin Creek	Snell Valley	Butts Creek
Upper Middletown	Putah Creek	Zim Zim	Eticuera Creek
Lower Crazy Creek	Crazy Creek	Upper Hardin	Hardin Creek
Guenoc	Putah Creek	Lower Hardin	Hardin Creek
Steinhart	Soda Creek	Lower Goodings	Maxwell Creek
Jerusalem	Soda Creek	Upper Capell	Capell Creek
Bucksnort	Bucksnort Creek	Lower Capell	Capell Creek
Noyes	Putah Creek		

For each of the sites chosen, reconnaissance estimates were made of the mean annual precipitation on the drainage area above the dam site, the mean annual runoff available at the dam site, the peak flow for the spillway design flood, the mean annual unit evaporation and local geologic conditions. Estimates of mean annual precipitation were based on records at the precipitation stations and a vailable isohyetal maps previously described in Chapter III. Estimates of mean annual runoff at the sites were derived from correlations of mean annual precipitation and mean annual runoff based on records of measured streams within and near Putah Creek Basin. These runoff values were reduced by estimates of present upstream impairments. Estimates of the peak flow for the spillway design flood were based on reconnaissance estimates of the 72-hour probable maximum precipitation, assumed loss rates, based on similar studies in adjacent areas, and unit hydrographs developed for gaged areas in and adjacent to the basin. Estimates of mean annual unit evaporation were based on records from some 30 evaporation measurement stations located within the Central Valley and tributary areas. Values of net evaporation rates were computed as the difference between gross evaporation and the consumptive use of precipitation by native vegetation in the reservoir area. The results of these estimates of hydrologic factors at the chosen sites are presented in Table 21.

The relationships between storage capacity and reservoir yield were determined on the basis of regional storage-development curves for the gaged areas of the basin. In constructing these curves, the monthly distribution of annual yield was based on an irrigation demand schedule as presented in Table 22.

TABLE 21

ESTIMATES OF GENERAL AND HYDROLOGIC DATA
AT SELECTED DAM AND RESERVOIR SITES IN UPPER PUTAH CREEK BASIN

Dam and reservoir site	Location of dam site[a/]				Drainage area, in square miles	Estimated mean annual precipitation, in inches	Estimated mean annual present impaired runoff, in acre-feet	Estimated peak inflow of spillway design flood, in second feet	Estimated mean annual net unit evaporation, in feet
	Stream	Section	Township	Range					
			LAKE COUNTY						
Dry Creek	Dry Creek	4 & 9	10N	7W	8.3	75	22,400	10,000	2.7
Saint Helena [b/]	St. Helena Creek	26	10N	7W	7.7	64	14,500	8,000	2.7
Middletown	Putah Creek	15	11N	7W	67.4	56	102,600	52,000	2.8
Putah Creek Canyon	Putah Creek	14	11N	7W	85.3	55	122,300	64,000	2.8
Crazy Creek	Crazy Creek	25	11N	7W	c/	42	c/	c/	2.8
Coyote Creek	Coyote Creek	18	11N	6W	5.5	38	11,000	5,000	2.8
Big Canyon [b/]	Big Canyon Creek	10	11N	6W	13.6	50	16,700	12,000	2.8
Enlarged Detert & McCreary	Bucksnort Creek	9 & 34	10N 11N	6W 6W	10.6	49	13,900	7,000	2.8
			NAPA COUNTY						
James Creek [b/]	James Creek	36	10N	6W	10.9	51	13,700	7,000	2.9
Swartz Creek	Swartz Creek	11	9N	6W	5.9	53	8,000	5,000	2.9
Upper Maxwell	Maxwell Creek	35	9N	5W	6.9	32	3,700	5,000	3.0
Walter Springs	Pope Creek	12	9N	5W	48.4	38	34,800	24,000	3.0
Goodings	Maxwell Creek	19	9N	4W	33.3	31	16,300	16,000	3.0
Capell Creek	Capell Creek	20	7N	3W	8.3	32	4,600	5,000	2.9
Adams	Eticuera Creek	22	10N	4W	54.0	25	17,200	22,000	3.0

a/ Where a dam site is located in a former land grant area, section lines were extended to facilitate description of their locations.

b/ Diversion dam to augment the yield of nearby potential storage reservoirs.

c/ Relatively small drainage area and runoff which are considered negligible because this site is for off-stream storage in conjunction with Middletown and Putah Creek Canyon Reservoirs.

TABLE 22

ESTIMATED AVERAGE MONTHLY DISTRIBUTION OF ANNUAL AGRICULTURAL DEMAND FOR WATER

Month	Estimated average irrigation demand for water, in percent of annual total	Month	Estimated average irrigation demand for water, in percent of annual total
October	5	April	5
November	0	May	9
December	0	June	17
January	0	July	26
February	0	August	21
March	0	September	17
		TOTAL	100

Safe yield, the maximum sustained annual draft that could have been maintained throughout a critically deficient period of water supply during the period of record, reflects abnormally dry conditions, and is below the yield that could be obtained in most years. Studies to determine the water supply deficiency that might be endured without permanent injury to perennial crops have not been made for the Upper Putah Creek Basin but have been made for other areas of California. The results of these studies indicate that a maximum annual deficiency of 35 percent of the full seasonal water requirement can be endured if the deficiency occurs only at relatively long intervals. It has also been established that small deficiencies occurring at relatively frequent intervals can be endured. Therefore, because the safe annual yield reflects abnormally dry conditions, and because a greater and more realistic use of water for irrigation purposes could be made by allowing an occasional deficiency, estimates of firm annual reservoir yield contained herein have been adjusted to allow for a maximum annual deficiency of 35 percent, but were limited by an average annual deficiency not in excess of 2 percent per year during the entire

50-year mean period. For those reservoirs which would primarily be used for domestic purposes, estimates of annual yield have been computed on a safe yield basis with no deficiency.

Reconnaissance cost estimates were made for the remaining 12 dams and reservoir sites investigated. Estimates of cost and reservoir yield were made for several sizes of reservoirs at most of the sites. Detailed spillway designs were not made, but freeboard between normal pool elevation and dam crest elevation was provided in sufficient amount to allow for passage of the maximum probable flood over a reasonably sized spillway. These preliminary studies resulted in approximate figures, which were sufficiently accurate for comparative purposes. Some of the comparisons made between alternative dam sites were size versus cost per acre-foot of water, and capital cost per acre-foot of storage capacity.

Construction costs of dams and appurtenant structures were based on total volume of earth embankment and average recent bid costs (from 1958 to 1960) of dam and appurtenances per cubic yard of embankment. These bid costs are shown in Table 23. A value of $2.00 per cubic yard of earth embankment was used in estimates of construction.

In addition to the costs of construction, estimates of capital costs included allowances for acquisition of land and improvements, relocation of roads, reservoir clearing, contingencies, administration, engineering, and interest during the construction period. Estimates of annual costs, included interest on the capital investment at four percent per annum, amortization over a 50-year repayment, and allowances for replacement, office and overhead expenses, and operation and maintenance costs.

TABLE 23

SUMMARY OF COST DATA FOR SIX RECENTLY COMPLETED DAMS AND ESTIMATE OF AVERAGE UNIT CAPITAL COST

Name of dam and reservoir	Height of dam, in feet	Length of dam crest, in feet	Total volume of earth embankment, in cubic yards	Bid cost of dam and appurtenances, in dollars per cubic yard		
				Successful low bidder	Average of all bids	High bidder
Terminus	250	2,375	7,128,000	1.33	1.60	1.78
Prosser Creek	150	1,840	1,739,000	1.25	1.70	2.11
Union Valley	400	1,880	10,118,000	1.34	1.89	2.44
Whale Rock	210	850	2,500,000	1.27	1.56	2.16
Trinity	505	2,450	29,000,000	1.70	1.81	1.91
Miramar	148	1,190	830,000	1.63	1.86	2.38
Average unit cost of construction				1.42	1.74	2.13
Engineering and administration, 10%				.14	.17	.21
Subtotals				1.56	1.91	2.34
Interest during construction, 4% for 1/2 of construction period[a]				.06	.08	.09
AVERAGE UNIT CAPITAL COST OF STRUCTURE[b]				1.62	1.99	2.43

a Assumed length of construction period for dams in the Upper Putah Creek Basin is 2 years.

b Does not include costs of acquisition of lands and improvements, relocations of roads, and reservoir clearing which were estimated individually for each site.

General Engineering Properties of Geologic Formations

The materials comprising the various geologic formations of the Upper Putah Creek Basin display wide variations in composition, texture, and strength, which determine their suitability for use in hydraulic structures. In general, these characteristics depend on their geologic history. A generalized description of engineering properties such as workability, stability of cut-slopes, foundation conditions, and possible uses of materials of the various geologic formations of the Upper Putah Creek Basin are presented in Table 24. The general location of these formations is shown on Plate 4. The physical and water-bearing characteristics of these formations were discussed previously in Chapter IV and summarized in Table 17.

TABLE 24

GENERALIZED DESCRIPTION OF ENGINEERING PROPERTIES OF GEOLOGIC FORMATIONS IN UPPER PUTAH CREEK BASIN

Geologic unit and map symbol	Workability	Estimated cut slope stability	Foundation conditions		Possible or reported use
			Earth or rockfill dam	Canal	
Landslides Qls	Common excavation, large blocks may be expected, fairly easily compacted.	Slopes generally unstable in deep cuts, slopes should be at least $2\frac{1}{2}$:1. Berms may be required.	Not suitable due to instability of mass. Should be completely removed.	Not suitable, canal should be routed around slide areas.	May be used for impervious fill, must be processed to remove boulders.
Alluvium Qal	Common excavation, easy to compact except where organic content is high. May contain ponded water which would affect workability.	Slopes unstable in steep cuts, slopes should be $1\frac{1}{2}$:1. Berms may be required.	Generally not suitable beneath impervious section. If organic content is high, not suitable beneath pervious section.	Generally good, probably will require 100% lining.	Can be processed for impervious or pervious fill, (depending on clay content). Along stream channels is used as source of aggregate.
Clear Lake Volcanics Qv	Weathered: 40% common excavation, will require light blasting. Nonweathered: Hard rock excavation.	Slopes stable at 1:1, may require berms. Slopes stable at $\frac{1}{2}$:1.	Not suitable for impervious section, should be completely removed. Suitable for all types. Some leakage may be expected.	Good. Some leakage may be expected. Good. Some flume may be required.	May be used for impervious fill after testing. May be quarried for use as rockfill or riprap.
Clear Lake Volcanics, Basalt Member Qpvb	Weathered: 50% common excavation, may require some light blasting. Nonweathered: Hard rock excavation.	Slopes stable at 1:1. Slopes stable at $\frac{1}{2}$:1.	Not suitable for impervious section, should be completely removed. Suitable for all types. Some leakage may be expected.	Good, Some leakage may be expected. Good. Some flume may be required.	May be used for impervious fill after testing. May be quarried for use as rockfill or riprap.

Sheet 1 of 3

GENERALIZED DESCRIPTION OF ENGINEERING PROPERTIES OF GEOLOGIC FORMATIONS IN UPPER PUTAH CREEK BASIN

Geologic unit and map symbol	Workability	Estimated cut slope stability	Foundation conditions		Possible or reported use
			Earth or rockfill dam	Canal	
Tuff TQp	90% common excavation, is rippable, may require light blasting.	Slopes stable at 1:1 to nearly vertical depending on attitude of beds.	Not suitable except for low structures.	Fair, some leakage may be expected.	Not usable.
Cache Formation TQc	Common excavation, is rippable.	Slopes stable at 1:1, berms may be required on higher cuts.	Good for fill structure of moderate height. Some leakage may be expected.	Good, may require some lining.	May be used for impervious fill.
Sonoma Volcanics Tsv	Weathered: 80% Common, some light blasting may be required.	Slopes stable at 3/4:1, may require some berms.	Not suitable.	Good, some leakage may be expected.	Soil and tuff may be used for impervious fill, flow rocks for riprap.
	Nonweathered: 30%-50% common excavation, some heavy blasting may be required.	Slopes stable at $\frac{1}{4}$:1.	Good for any structure. Some leakage may be expected.	Good. Some flume may be required.	Same as above.
Martinez Formation Tmz	50% common excavation. Partly rippable, some light blasting may be required.	Slopes stable at 1:1 to nearly vertical depending on attitude of beds.	Does not apply.	Does not apply.	Not used.
Cretaceous Sediments Undifferentiated K	90% common excavation in mudstone, 75% hard rock excavation in massive sandstone.	Slopes stable at 1:1 to nearly vertical depending on amount of mudstone and attitude of beds.	Good for any structure.	Good, some lining may be required.	Sandstone may be used for riprap.
Detrital Serpentine dsp	80% common excavation, rippable, some large blocks may be expected.	Slopes probably stable at 2:1, may require berms.	Not suitable.	Not suitable	Not used.

Sheet 2 of 3

TABLE 24 (Continued)

GENERALIZED DESCRIPTION OF ENGINEERING PROPERTIES OF GEOLOGIC FORMATIONS IN UPPER PUTAH CREEK BASIN

Geologic unit and map symbol	Workability	Estimated cut slope stability	Foundation conditions		Possible or reported use
			Earth or rockfill dam	Canal	
Franciscan Knoxville Groups Undifferentiated Jfk	80% common excavation, light to heavy blasting.	Slopes stable at 2:1, to 1:1 in shale, $\frac{1}{2}$:1 in graywacke.	Good for any structure, shales may require specially designed structures.	Good, some lining may be required.	Graywacke may be used for riprap.
Basalt Jb	Hard rock excavation.	Slopes stable at $\frac{1}{2}$:1.	Good for any structure.	Good. Some flume may be required.	Riprap.
Schist sch	Hard rock excavation.	Slopes stable at $\frac{1}{2}$:1.	Good for any structure.	Good.	Riprap, rockfill.
Serpentine Jsp	50% common excavation, light to moderate blasting required.	Slopes stable at $1\frac{1}{4}$:1 to 1:1, berms are necessary.	Fair, leakage may be expected, structures should have flat slopes.	Fair, leakage may be expected.	Not used.
Basic Intrusives Jbi	Hard rock excavation.	Slopes stable at $\frac{1}{2}$:1.	Good for any structure.	Good. Some flume may be required.	Riprap, rockfill.
Greenstone gs	Hard rock excavation.	Slopes stable at $\frac{1}{2}$:1.	Good for any structure.	Good. Some leakage may be expected.	Riprap, rockfill.

Sheet 3 of 3

Seismicity

The area encompassed by the Upper Putah Creek Basin lies in a region of moderate to high seismic activity. Two scales are generally used to measure this activity. The Richter magnitude scale represents an instrumentally determined measurement of the size of an earthquake. The Modified Mercalli scale is a qualitative, numerical rating of the effects of an earthquake at a given point.

Records of the United States Coast and Geodetic Survey (Reference 31) list two significant earthquakes since 1934 with epicenters within the Upper Putah Creek Basin. These had Richter magnitudes of 4.0 and 4.1. The entire basin lies within a region having a probable maximum intensity, on the Modified Mercalli scale, of VIII (Reference 21). The value applies to areas of solid igneous and consolidated sedimentary rocks. Locally, on unconsolidated alluvium, the expected maximum seismic intensity is IX.

The Modified Mercalli Scale of Intensity varies from I (weak) to XII (extreme). A brief summary of the effects that may be expected from shocks of specific intensities are as follows:

I to V	Minor, very little damage to structures.
VI	Felt by all, many frightened. Trees and bushes shaken slightly. Liquids set in strong motion. Damage slight in poorly built buildings.
VII	Frightened all, general alarm all run outdoors. May be difficult to stand. Waves on ponds, lakes, and running water. Water turbid. Incaving of sand and gravel banks. Damage negligible to structures of good design and construction.
VIII	Fright general, alarm approaches panic. Notices by persons driving automobiles. Trees shaken strongly. Changes in flow of wells and springs. Damage slight in specially designed structures, partial collapse in ordinary substantial buildings.
IV	Panic general, ground cracked conspicuously. Underground pipes broken. Serious damage to reservoirs and well-designed structures. Partial collapse of other structures.
X to XII	Serious to total damage to all structures. Lines of sight distorted. Earth slumps and landslides common.

Dry Creek Dam and Reservoir

The Dry Creek dam site is located in Lake County on Dry Creek about 2 miles southwest of Middletown near the northwest corner of Section 9, T4N, R4W, MDB&M. Conserved waters from Dry Creek could be augmented by gravity diverted flows from St. Helena Creek and would be best suited for supplying supplemental water by gravity for urban or irrigation purposes in the Collayomi-Long Valleys service area.

The service area comprises an estimated net irrigable area of about 4,700 acres. The community of Middletown, which is included in the service area, is expected to expand from its present population of 450 people to about 3,500 people during the next 60 years. For the most part, this population expansion can reasonably be expected to take place on lands classified as irrigable. Under full development, it is estimated that the average annual water requirement in the service area would range from about 10,000 to 13,500 acre-feet, depending upon the types of crops being irrigated and the amount of irrigable land devoted to urban use. In Chapter II it was estimated that the most likely value of future water requirements in the service area would range from about 8,700 to 11,000 acre-feet per year depending upon the adequacy and reliability of the presently developed supply.

In addition to water conservation, the Dry Creek site has a considerable potential for outdoor recreation. Although much of the terrain surrounding the reservoir is steep, areas could be leveled to provide facilities for swimming, picnicking, boating, and fishing.

A topographic map of the dam and reservoir site was prepared by photogrammetric methods at a scale of one inch equals 300 feet, with

20. Lower reaches of Dry Creek drainage area. Artist's illustration shows location of the proposed Dry Creek Dam.

21. St. Helena Creek diversion dam site. Waters diverted from this stream would augment the yield obtainable from Dry Creek Reservoir.

a contour interval of 10 feet. Reservoir areas, storage capacities, and estimates of required quantities of construction materials for the dam were computed from this map. United States Geological Survey quadrangles, at a scale of 1:24,000 with a 40-foot contour interval, were utilized to select the location and estimate the cost of the diversion and feeder canal from St. Helena Creek.

Studies of Dry Creek Dam and Reservoir included the evaluation of three alternative axes for the dam. The middle axis appears to be the most favorable for all but the minimum amount of storage and has been selected for presentation in this bulletin. The upper axis, about 1,200 feet upstream, appears to be the most favorable for reservoirs of less than 4,000 acre-feet storage. This axis is presently being considered by the Middletown County Water District. Location of the Dry Creek Dam and Reservoir site and a possible feeder canal from St. Helena Creek is shown on Plate 5. The stream bed elevations at the Dry Creek Dam site and the St. Helena diversion site are about 1,170 and 1,340 feet, respectively.

The Dry Creek Dam site appears to be suitable for an earthfill structure of moderate height. Bedrock consists of Franciscan graywacke, chert, and shale with lesser amounts of schist, greenstone, and basalt. These rocks are generally interbedded, strike approximately normal to Dry Creek, and dip steeply from about 60 degrees downstream to almost vertical. Outcrops of fractured and weathered bedrock occur at the base of the left abutment and locally on the slopes of each abutment. Major faulting at the dam site is not indicated but evidence of four minor fault zones was observed. One fault is located on the right abutment and crosses the axis about 130 feet above stream bed. Two others are located in saddles above the left abutment. The fourth fault crosses the left abutment about 50 feet above stream bed and probably would require special treatment in the foundation area to prevent excessive leakage. Foundation preparation would include moderate stripping of soil and weathered bedrock on both abutments and excavation of alluvial sands, gravels, and weathered rock in the channel section. Grouting would be required in areas of jointed bedrock.

The spillway should be capable of safely passing an inflow flood with a peak discharge of about 10,000 second-feet. It appears that a concrete-lined chute-spillway across the left abutment near the end of the dam would have a suitable foundation.

Bedrock at the St. Helena Diversion dam site, located in Section 26, T10N, R7W, consists of serpentine of Jurassic age and is almost continuously exposed, except where it is covered by the road fill for State Highway 29. With proper treatment of the foundation area, this site appears to be suitable for a low diversion structure. Stripping for a low concrete diversion structure should include all road fill material and jointed and slightly weathered serpentine. With proper precautions, the road fill could be replaced along its present alignment. The alignment of the feeder canal would be partially in serpentine and partially in graywacke, shale, and associated rocks of the Franciscan group. These rocks are exposed locally along the conduit alignment but are generally covered by residual soil and slope wash.

Adequate quantities of construction materials may reasonably be expected to be found within five miles of the dam site. Pervious and impervious fill materials should be available from alluvial deposits along Dry Creek. Numerous potential quarry sites for riprap are to be found near the dam site.

The watershed of Dry Creek tributary to the site consists of about 8.4 square miles of heavy brush and wooded lands. The runoff of Dry Creek since May 1959 indicates a mean annual runoff of 22,400 acre-feet.1/ This flow could be augmented by gravity diversion from St. Helena Creek. The drainage area of St. Helena Creek above the diversion is about 7.7 square miles with an estimated mean annual runoff of 14,500 acre-feet.

Estimates were made of the amounts of water susceptible to diversion from St. Helena Creek for four sizes of conduit: 25, 50, 75, and 100 second-feet, respectively. Mean daily flows at the diversion site were assumed to occur in a similar pattern to recorded daily flow at Kelsey Creek and in direct proportion to the ratio of the mean estimated annual runoff of St. Helena Creek to Kelsey Creek. The estimated minimum, mean, and maximum annual quantities of water that could have been diverted by the four sizes of diversion conduit are presented in the following tabulation:

Conduit capacity, in second-feet	Estimated annual quantities of divertible water, in acre-feet		
	Minimum	Mean	Maximum
25	2,300	5,800	9,800
50	2,500	7,700	14,600
75	2,600	9,100	19,500
100	2,600	10,000	22,500

1/ Measured at U.S.G.S. gaging station "Dry Creek near Middletown" about 600 feet upstream from the middle axis of the Dry Creek Dam site.

Yields for various sizes of reservoirs were determined by semi-annual operation studies utilizing estimated diversions from St. Helena Creek combined with the estimated runoff of Dry Creek. These estimated yields are presented in Table 25.

TABLE 25

ESTIMATED ANNUAL YIELD OF DRY CREEK RESERVOIR

Reservoir storage capacity, in acre-feet	Estimated firm annual yield, in acre-feet				
	With Dry Creek only	With diversion, at indicated capacity, in cubic feet per second			
		25	50	75	100
2,200	2,300	2,600	2,600	2,600	2,600
4,200	4,200	5,300	5,300	5,300	5,300
6,600	6,400	8,200	8,300	8,300	8,300
9,900	8,600	11,100	11,200	11,200	11,200
14,000	10,700	13,500	13,800	14,000	14,000

Reconnaissance cost estimates were made for several heights of dam at the Dry Creek dam site, for a diversion dam on St. Helena Creek, and for a 25 second-foot feeder canal. A rolled earthfill structure with 3:1 upstream and downstream slopes for all heights of the main dam was assumed. It was assumed that the dam would be 10 feet in height and about 50 feet in length. The feeder conduit would extend about 7 miles in a northwesterly direction, from the diversion dam. About 4,000 feet of either elevated or benched flume would be required in problem areas along the canal route.

The capital cost of the Dry Creek dam and reservoir alone would range between about one million and 4.6 million dollars depending on height of structure. With the addition of the St. Helena Creek diversion works, these capital costs would be increased about $380,000 and the total would then range between about 1.3 and five million dollars.

A summary of the estimated capital costs, average annual costs, and unit costs of water for various sizes of dam and reservoir are presented in Table 26. Costs for various heights of dam, which include the costs of the St. Helena Creek diversion dam and feeder canal, are presented in Table 27.

It should be understood, in this and all subsequent estimates of unit cost of water, that the costs shown are unallocated costs. In a reservoir serving more than one purpose, a portion of these costs may be expected to be allocated to its other functions such as recreation and/or flood control. This would tend to reduce the estimated average annual unit cost allocated to conservation water by some factor which cannot be computed until a final project formulation and design is made and all costs allocated.

TABLE 26

SUMMARY OF RECONNAISSANCE ESTIMATES OF COSTS AND YIELDS FOR
DRY CREEK DAM AND RESERVOIR

Height of dam above stream bed, in feet	Normal water surface elevation USGS datum, in feet	Storage capacity, in acre-feet	Estimated firm annual yield, in acre-feet	Cost of dam and reservoir: Capital cost, in millions of dollars	Cost of dam and reservoir: Average annual cost, in thousands of dollars	Estimated average annual unit cost of water at dam 1/: Per acre-foot of firm annual yield, in dollars	Estimated average annual unit cost of water at dam 1/: Per acre-foot of incrementa firm annua yield, in dollars
80	1,242	2,200	2,300	1.0	49	21	
							14
100	1,262	4,200	4,200	1.5	75	18	
							17
120	1,282	6,600	6,400	2.2	113	18	
							24
140	1,302	9,900	8,500	3.2	164	19	
							31
160	1,322	14,000	10,700	4.6	231	22	

1/ Based on unallocated costs. If flood control, recreation, or other purposes are included, a portion of these costs may reasonably be expected to be allocated to the other functions of the reservoir. The degree to which these costs might be chargeable to such functions cannot be determined until final project formulation and design are completed.

TABLE 27

SUMMARY OF RECONNAISSANCE ESTIMATES OF COSTS AND YIELDS FOR DRY CREEK DAM AND RESERVOIR

(Including St. Helena Creek Diversion Works)1/

Height of dam above stream bed, in feet	Normal water surface elevation USGS datum, in feet	Storage capacity, in acre-feet	Estimated firm annual yield, in acre-feet	Estimated cost of dam, reservoir, and diversion works: Capital cost, in millions of dollars	Estimated cost of dam, reservoir, and diversion works: Average annual cost, in thousands of dollars	Estimated average annual unit cost of water at dam2/: Per acre-foot of firm annual yield, in dollars	Estimated average annual unit cost of water at dam2/: Per acre-foot of incremental firm annual yield, in dollars
80	1,242	2,200	2,600	1.3	68	26	
							10
100	1,262	4,200	5,300	1.9	94	18	
							13
120	1,282	6,600	8,200	2.6	132	16	
							16
140	1,302	9,900	11,100	3.5	179	16	
							28
160	1,322	14,000	13,500	5.0	250	19	

1/ Feeder canal capacity, 25 second-feet.

2/ Based on unallocated costs. If flood control, recreation, or other purposes are included, a portion of these costs may reasonably be expected to be allocated to the other functions of the reservoir. The degree to which these costs might be chargeable to such functions cannot be determined until final project formulation and design are completed.

Middletown Dam and Reservoir

The Middletown dam site is located in Lake County on Putah Creek, about $3\frac{1}{2}$ miles north of Middletown, in Section 15, T11N, R7W, MDB&M. An alternative site, 1,600 feet upstream, was rejected because of unfavorable geologic conditions. Another alternative site, the Putah Creek Canyon site located 0.6 miles downstream, is discussed in a subsequent portion of this chapter. Two sites on the adjacent Crazy Creek drainage area were also considered as possibilities for off-stream storage of Putah Creek waters in conjunction with the Middletown and Putah Creek Canyon sites. The lower site on Crazy Creek was rejected due to unfavorable geologic conditions. The upper site could be operated in conjunction with storage at the Middletown site and is presented as part of this discussion. The Crazy Creek dam site is located about 2 miles northeast of Middletown near State Highway 53, in Sections 30 and 31, T11N, R6W, MDB&M. Location of the Middletown and Crazy Creek dam and reservoir sites are shown on Plate 5.

Construction of the Middletown Dam and Reservoir, either with or without off-stream storage at Crazy Creek, would permit conservation of the winter storm runoff of Putah Creek and would supply supplemental water for gravity distribution to irrigable lands in the Coyote Valley service area. Of the 4,600 acres of land in the potential service area, about 400 acres are presently irrigated and an additional net area of 1,900 acres is considered suitable for irrigated agriculture. These additional lands, under full development, would require from 3,600 to 5,300 acre-feet of water annually, depending on the types of crops being irrigated. In Chapter II, it was estimated that about 4,000 acre-feet represents the most likely value of additional annual water requirement. This value, when added to the present requirement of 1,400 acre-feet, results in a total future average annual water requirement of about 5,400 acre-feet. Conserved waters could also be pumped, at added cost, to supply demands in the Collayomi-Long Valleys area, previously described in the presentation of the Dry Creek Project.

The drainage area of Putah Creek above the Middletown site is 67.4 square miles. Although records of runoff are not available at the site, it is estimated that the mean annual runoff is about 103,000 acre-feet.

A dam at the Middletown site was considered in The California Water Plan to serve local needs under ultimate conditions of development. Under that plan, a reservoir with a normal pool elevation of 1,080 feet, a storage capacity of 14,200 acre-feet, and an estimated annual yield of 16,000 acre-feet would have been provided. It was estimated that this reservoir, together with the yield from Detert reservoir plus utilization of ground water, would have been capable of meeting the ultimate requirements of the Middletown area.

However, because of possible drainage and mosquito breeding problems near Middletown, it was assumed for the purpose of this investigation, that the maximum feasible storage level at this site would be elevation 1,066 feet. At this elevation the reservoir would have a storage capacity of only 5,600 acre-feet. Because the reduced yield would be smaller than the combined water requirements of Coyote, Collayomi, and Long Valleys, consideration was given to off-stream storage on Crazy Creek.

Runoff at the Crazy Creek site is considered neglibible in comparison to that of Putah Creek.

In addition to water conservation, the Middletown Reservoir could provide some recreational use to local residents and recreationists visiting the Cobb Mountain resort area.

A topographic map of the Middletown and Crazy Creek dam and reservoir sites was prepared by photogrammetric methods at a scale of one inch equals 300 feet, with a contour interval of 10 feet. Reservoir areas, storage capacities, and estimates of required quantities of construction materials were computed from this map. Stream bed elevation is about 1,020 feet at the Middletown dam site and about 1,000 feet at the Crazy Creek dam site. The two reservoir areas are separated by a saddle with natural ground elevation of 1,075 feet so that the ability of the off-stream storage reservoir to regulate Putah Creek runoff can be preset by placement of a suitable control structure at this point. Based on a brief geological reconnaissance, the Middletown and Crazy Creek sites appear to be suitable for construction of earthfill structures of moderate height. At the Middletown dam site, the maximum feasible height would be limited to about 60 feet because of a narrow ridge forming the right abutment, which might be subject to excessive leakage under high heads and the necessity of controlling surcharge storage encroachment near Middletown during periods of flood runoff into a full reservoir.

The Middletown dam site is underlain by hard to moderately hard, bedded sandstone and shale of Cretaceous age. Bedrock is exposed on the right abutment in large jointed outcrops, but exposure elsewhere is poor. Recent alluvium fills the active channel and forms a terrace 90 feet in width at the base of the left abutment, with an estimated average depth of 20 feet and maximum depth of 40 feet.

Foundation preparation of the abutments would require moderate depths of stripping for removal of soil and loose rock. In the channel section, removal of the entire terrace deposits probably would be required and stripping in the cut-off area should be extended to bedrock.

Off-stream storage at the Crazy Creek site would be accomplished by construction of a dam and an equally sized dike. The dike site has a 200-foot wide channel section and rather uneven abutments. Gabbro breccia would underlie the main dam and the left abutment of the dike. The right abutment of the dike is composed of shale with occasional sandstone interbeds. Recent alluvium and slopewash fill the valley flats and channel sections at both the dam and dike sites.

Foundation preparation for the dam on Crazy Creek would require moderate stripping of alluvium with a few feet of bedrock shaping in the channel section. The left abutment would require moderate stripping of soil with additional hardrock shaping for the impervious section. It appears that at least 10 feet of stripping would be required for the right abutment and some subsurface materials testing will be required to adequately appraise foundation conditions. Moderate to heavy stripping of alluvium would be required in the channel section.

Spillway placement would be dependent on whether Middletown Dam and Reservoir were built alone, or in conjunction with the Crazy Creek

Reservoir. The spillway for the Middletown site along could be constructed across the narrow ridge of the right abutment where depth to sound rock is about 10 feet. A lined chute spillway would be required.

The spillway would be placed in a saddle leading to Crazy Creek Reservoir. Waters from Putah Creek would first fill the storage in Middletown Reservoir and would then spill excess water and flood runoff into Crazy Creek Reservoir. A lined chute spillway on the hill between the dam and the dike at the Crazy Creek Dam site would adequately discharge an inflow flood of about 52,000 cubic feet per second.

The cut in the saddle between the two reservoir areas would require a weir and a lined discharge channel into the Crazy Creek Reservoir area. The saddle is underlain by shales of Cretaceous and Jurassic ages of the Knoxville group. These are separated by a serpentine intruded fault zone. Firm rock in the shales may exist only at considerable depths. Subsurface exploration is needed to ascertain the foundation conditions. It appears that some over-excavation and backfilling with concrete would be required at the weir between the two reservoir areas.

Sufficient quantities of pervious materials could be obtained from alluvial deposits along Putah Creek. Impervious materials may be obtained from soil and slopewash within one mile of the dam sites. Potential quarry sites exist in a massive sandstone bed about one-half mile upstream from the Middletown dam site. Rock would also be available from spillway excavations.

Reconnaissance cost estimates were made for several heights of dam at the Middletown site. Cost estimates were also made for a dam 60 feet in height at the Middletown site, combined with various heights of dam at the Crazy Creek off-stream storage site. A freeboard allowance of 14 feet was used for both reservoirs in estimating the reservoir capacities. Although no costs are included for distribution systems to the service areas, it should be noted that outlet works at both Middletown and Crazy Creek dams would be required to dewater the storage in each reservoir. Two outlets would also facilitate the service of water to irrigable areas of Coyote, Collayomi, and Long Valleys. The distribution system to farmers' head gates would thus be shorter and would result in less channel loss and lowered maintenance costs.

The capital cost of the Middletown project alone would range from $500,000 to $900,000 depending on height of structure. Capital costs for the combined Middletown-Crazy Creek project would range from $1,700,000 to $2,700,000 depending on the height of Crazy Creek dam. These costs include an allowance for required relocation of parts of State Highway 53 and Big Canyon Creek road. A summary of the estimated capital cost, average annual costs, and unit cost of water for various sizes of dam and reservoir at the Middletown site is presented in Table 28. Similar cost data for the combined Middletown-Crazy Creek project are presented in Table 29. It should be remembered that these are unallocated costs as described in the discussion of the Dry Creek Reservoir.

TABLE 28

SUMMARY OF RECONNAISSANCE ESTIMATES OF COSTS AND YIELDS FOR MIDDLETOWN DAM AND RESERVOIR

				Cost of dam and reservoir		Estimated average annual unit cost of water at dam 1/	
Height of dam above stream bed, in feet	Normal water surface elevation USGS datum, in feet	Storage capacity, in acre-feet	Estimated firm annual yield, in acre-feet	Capital cost, in millions of dollars	Average annual cost, in thousands of dollars	Per acre-foot of firm annual yield, in dollars	Per acre-foot of incremental firm annual yield, in dollars
50	1,056	2,800	2,300	0.5	24	10	
							6
55	1,061	4,100	3,700	0.6	32	9	
							8
60	1,066	5,600	5,600	0.9	47	8	

1/ Based on unallocated costs. If flood control, recreation, or other purposes are included, a portion of these costs may reasonably be expected to be allocated to the other functions of the reservoir. The degree to which these costs might be chargeable to such functions cannot be determined until final project formulation and design are completed.

TABLE 29

SUMMARY OF RECONNAISSANCE ESTIMATES OF
COSTS AND YIELDS FOR MIDDLETOWN DAM AND RESERVOIR IN CONJUNCTION WITH
VARIOUS SIZES OF OFF-STREAM STORAGE RESERVOIR ON CRAZY CREEK

Crazy Creek Dam and Reservoir		Combined Middletown-Crazy Creek Project					
				Cost of dams and reservoirs		Estimated average annual unit cost of water at dam 2/	
Height of dam above stream bed, in feet	Normal water surface élevation USGS datum, in feet	Storage capacity in 1/ acre-feet	Estimated firm annual yield, in acre-feet	Capital cost, in millions of dollars	Average annual cost, in thousands of dollars	Per acre-foot of firm annual yield, in dollars	Per acre-foot of incremental firm annual yield, in dollars
50	1,036	7,100	7,300	1.7	86	12	
							9
60	1,046	8,600	9,100	2.0	103	11	
							9
70	1,056	10,100	10,800	2.3	118	11	
							9
80	1,066	12,100	13,000	2.7	137	10	

1/ The height of the Crazy Creek Dam would not affect the storage capacity of Middletown Reservoir. Middletown Reservoir would have a storage capacity of 5,600 acre-feet, which would be established by a spillway between the two reservoirs at an elevation of 1,066 feet.

2/ Based on unallocated costs. If flood control, recreation, or other purposes are included, a portion of these costs may reasonably be expected to be allocated to the other functions of the reservoir. The degree to which these costs might be chargeable to such functions cannot be determined until final project formulation and design are completed.

Putah Creek Canyon Dam and Reservoir

The Putah Creek Canyon dam site is located in Lake County about four miles north of the town of Middletown in Section 14, T11N, R7W, MDB&M. The site is on Putah Creek, about one-half mile below its confluence with Big Canyon Creek, and 0.6 miles below the alternative Middletown dam site. The potential service area and water requirements are the same as those previously described for the Middletown site. Similar to Middletown reservoir, this reservoir would be suitable for conjunctive operation with off-stream storage on Crazy Creek. With stream bed elevation at 995 feet, the Putah Creek Canyon site affords more storage capacity, a larger drainage area and mean annual runoff, larger irrigation yield, and is competitive with the Middletown site in certain capacity combinations with the off-stream storage site on Crazy Creek.

In addition to water conservation, the Putah Creek Canyon reservoir has a somewhat better recreational potential than the Middletown site. The reservoir surface area would be larger than that of Middletown Reservoir and would be suitable for high speed boating and water skiing.

Topographic maps of the Middletown-Crazy Creek project, at a scale of one inch equals 300 feet, also covered the Putah Creek Canyon dam and reservoir site. Reservoir areas, storage capacities, and estimates of required quantities of construction materials were computed from this map. Location of the Putah Creek Canyon-Crazy Creek project is shown on Plate 5.

Based on a brief geologic reconnaissance, the Putah Creek Canyon Dam site appears to be suitable for an earthfill structure of moderate height. The channel is about 300 feet wide at the site and is bounded by steep abutments. The abutments are covered by soil and slopewash with outcrops of weathered and jointed sandstone and shale of Cretaceous age. The broad channel section is filled by recent alluvium to an estimated average depth of 50 feet.

Foundation preparation would include moderate stripping of soil and weathered bedrock on the abutments. In the channel section stripping would be considerable to insure proper cutoff but could be moderate under the pervious section, provided, after testing, that the alluvium is found to be suitable as a foundation material.

The spillway should be capable of passing an inflow flood with a peak discharge of about 64,000 cubic feet per second. For Putah Creek Canyon dam and reservoir alone, a lined chute spillway on the left abutment with a cut conveyance channel and re-entrance 500 feet downstream would be adequate. A freeboard allowance of 20 feet was used in estimating storage capacity of the reservoir. As in the case of the Middletown dam, when Putah Creek Canyon site is considered in conjunction with Crazy Creek reservoir, a weir would be installed in the saddle between the two reservoir areas and the spillway would be placed on the hill between the main dam and dike at the Crazy Creek site. In this case, a total freeboard allowance of 14 feet was used in estimating combined storage capacity of the two reservoirs. In order to utilize this storage capacity, outlet works at both Putah Creek Canyon and Crazy Creek dams would be required.

Construction materials are available in the vicinity of the Putah Creek Canyon site. The geology and availability of materials for the Crazy Creek off-stream storage portion of this project has been presented previously in the discussion of the Middletown dam and reservoir site.

There are no records of runoff for the 85.3 square miles of drainage area above the Putah Creek Canyon dam site. The watershed above the site drains about 75 percent of the total drainage above the United States Geological Survey gaging station, "Putah Creek near Guenoc", and is estimated to produce about 86 percent of the 50-year mean annual runoff at the gage. Therefore, it is estimated that mean annual runoff at the dam site would be about 124,000 acre-feet.

Reconnaissance cost estimates were made for several heights of dam at the Putah Creek Canyon site (and for an 85-foot dam) in conjunction with various heights of dam at the Crazy Creek off-stream storage site. Rolled earthfill structures with 3:1 upstream and downstream slopes were used to estimate costs for all sizes of dams considered.

The capital cost of the Putah Creek Canyon project alone would range between $1,000,000 and $1,600,000 depending on height of structure. The capital cost of the combined Putah Creek Canyon-Crazy Creek project would range from $2,300,000 to $3,300,000 depending on height of Crazy Creek dam. A summary of the estimated capital costs, average annual costs, and unit cost of water for various sizes of dam and reservoir at the Putah Creek Canyon site is presented in Table 30. Similar cost data for the combined Putah Creek Canyon-Crazy Creek project are presented in Table 31. These cost figures are unallocated costs as presented in the discussion of Dry Creek Dam and Reservoir.

TABLE 30

SUMMARY OF RECONNAISSANCE ESTIMATES OF COSTS AND YIELDS FOR PUTAH CREEK CANYON DAM AND RESERVOIR

Height of dam above stream bed, in feet	Normal water surface elevation USGS datum, in feet	Storage capacity in acre-feet	Estimated firm annual yield, in acre-feet	Cost of dam and reservoir: Capital cost, in millions of dollars	Cost of dam and reservoir: Average annual cost, in thousands of dollars	Estimated averag annual unit cost of water at dam 1/: Per acre-foot of firm annual yield, in dollars	Estimated averag annual unit cost of water at dam 1/: Per ac foot incremen firm an yield, i dolla
75	1,050	3,300	2,800	1.0	50	18	
80	1,055	4,750	4,300	1.2	62	14	8
85	1,060	6,200	6,000	1.6	79	13	10

1/ Based on unallocated costs. If flood control, recreation, or other purposes are included, a portion of these costs may reasonably be expected to be allocated to the other functions of the reservoir. The degree to which these costs might be chargeable to such functions cannot be determined until final project formulation and design are completed.

TABLE 31

SUMMARY OF RECONNAISSANCE ESTIMATES OF COSTS AND YIELDS FOR PUTAH CREEK CANYON DAM AND RESERVOIR, IN CONJUNCTION WITH VARIOUS SIZES OF OFF-STREAM STORAGE RESERVOIR ON CRAZY CREEK

Crazy Creek Dam and Reservoir		Combined Putah Creek Canyon-Crazy Creek Project					
				Cost of dams and reservoirs		Estimated average annual unit cost of water at dams 2/	
Height of dam above stream bed, in feet	Normal water surface elevation USGS datum, in feet	Storage capacity in 1/ acre-feet	Estimated firm annual yield, in acre-feet	Capital cost, in millions of dollars	Average annual cost, in thousands of dollars	Per acre-foot of firm annual yield, in dollars	Per acre-foot of incremental firm annual yield, in dollars
50	1,036	10,200	10,900	2.3	119	11	
							10
60	1,046	11,700	12,500	2.7	135	11	
							9
70	1,056	13,200	14,100	3.0	150	11	
							9
80	1,066	15,200	16,100	3.3	169	10	

1/ The height of the Crazy Creek Dam would not affect the storage capacity of Putah Creek Canyon Reservoir. Putah Creek Canyon Reservoir would have a storage capacity of 8,700 acre-feet, which would be established by a spillway between the two reservoirs at an elevation of 1,066 feet.

2/ Based on unallocated costs. If flood control, recreation, or other purposes are included, a portion of these costs may reasonably be expected to be allocated to the other functions of the reservoir. The degree to which these costs might be chargeable to such functions cannot be determined until final project formulation and design are completed.

22. Putah Creek at Middletown dam site. Artist's illustration shows approximate location of proposed dam.

23. Coyote Creek dam site and reservoir area--a possible surface storage project to serve Coyote Valley. Because of the limited drainage area and runoff, this project would require a diversion from nearby Big Canyon Creek.

Coyote Creek Dam and Reservoir

The Coyote Creek Dam site is located in Lake County on Coyote Creek, about five miles northeast of Middletown, in Section 18, T11N, R6W, MDB&M. Coyote Creek Reservoir would provide off-stream storage for gravity diverted surplus water from Big Canyon Creek and would be best suited for supplying supplemental water for irrigation purposes in the Coyote Valley Service Area. As previously discussed, the estimated future average annual water requirement for full development of the area would be about 5,400 acre-feet. The amount of new water development needed would be between 4,000 and 5,400 acre-feet per year depending on the adequacy and reliability of the presently developed supply.

In addition to water conservation, the Coyote Creek Reservoir has considerable potential for development of day-use recreational facilities. Slopes surrounding the reservoir area are generally moderate, supporting stands of oak interspersed with chaparral and digger pine.

Topography at the dam and reservoir site is shown on United States Geological Survey quadrangles at scales of 1:62,400 and 1:24,000 with contour intervals of 50 feet and 40 feet, respectively. These maps were utilized to determine reservoir areas and storage capacities, to select the location of the diversion dam and alignment of the conduit from Big Canyon Creek, and to estimate required quantities of construction materials. Location of the Coyote Creek Dam and Reservoir site and the Big Canyon diversion works are shown on Plate 5. The stream bed elevation at Coyote Dam and Big Canyon diversion sites are about 1,000 and 1,270 feet respectively, United States Geological Survey datum. Dikes would be required in three saddles for the higher sizes of dam.

Based on a brief geologic reconnaissance, the Coyote Creek Dam site appears to be suitable for an earthfill structure of moderate height. Bedrock at the site consists of tuffaceous silty gravel of the Cache formation, and basalt of the Clear Lake volcanics. These formations outcrop on both abutments of the dam site and some leakage may be anticipated through the Cache sediments, especially on the left abutment. A fault crosses the right abutment and channel section at the dam axis. In general, foundation preparation would include moderate stripping of soil and weathered rock on both abutments and excavation of alluvial sands and gravels in the channel section. Special treatment would be required to control leakage.

The spillway should be capable of passing an inflow flood with a peak discharge of about 5,000 second-feet. For the intermediate sizes of dam, a lined spillway could be placed in a saddle about $\frac{1}{2}$ mile northwest of the end of the dam on the right abutment.

Construction materials may be expected to be available within reasonable distance of the dam site. Impervious fill materials should be obtainable from the Cache formation in the reservoir area and pervious materials and concrete aggregate are readily available from alluvial deposits along Putah Creek. Basalt outcrops on the abutments appear to afford potential quarry sites for riprap.

The Big Canyon Creek Diversion dam site is underlain by fairly hard shale of the Knoxville group of Jurassic age and appears to be suitable for a low diversion dam. Stripping for a low concrete diversion structure should include removal of soil, roadfill, and loose weathered bedrock. With proper precautions, the roadfill could probably be replaced along its present alignment. The diversion conduit alignment would be partially in Recent terrace deposits, serpentine and Knoxville shale of Jurassic age, and in interbedded shale and sandstone of Cretaceous age. The conduit would cross a fault separating the serpentine and the cretaceous shales and sandstones.

There are no records of runoff for the 5.5 square-mile area tributary to the Coyote Creek dam site nor for the 13.6 square-mile area tributary to the Big Canyon Creek diversion dam site. However, it is estimated that mean annual runoff from these drainage areas would be 4,000 and 16,700 acre-feet, respectively. Estimates were made of the amounts of water susceptible to diversion from Big Canyon Creek for four sizes of conduits: 25, 50, 75, and 100 second-feet respectively. Mean daily flow at the diversion site was assumed to occur in a similar pattern to recorded daily flow of Kelsey Creek and in direct proportion to the ratio of the estimated mean annual runoff of Big Canyon Creek to Kelsey Creek at, the United States Geological Survey stream gaging station near Kelseyville. The estimated minimum, mean, and maximum annual amounts of water that could be diverted by the four sizes of diversion conduits are presented in the following tabulation:

Conduit capacity, in cubic feet per second	Estimated annual quantities of divertible water, in acre-feet		
	Minimum	Mean	Maximum
25	2,300	5,800	9,800
50	2,500	7,700	14,600
75	2,600	9,100	19,500
100	2,600	10,000	22,500

Yields for various sizes of reservoirs were determined by semi-annual operation studies utilizing estimated divertible water from Big Canyon Creek combined with the estimated runoff of Coyote Creek. The resultant yields of Coyote Creek Reservoir are presented in Table 32.

TABLE 32

ESTIMATED FIRM ANNUAL YIELD OF COYOTE CREEK RESERVOIR

Reservoir storage capacity, in acre-feet	Estimated firm annual yield, in acre-feet				
	With Coyote Creek alone	With diversion from Big Canyon Creek at indicated capacity, in cubic feet per second			
		25	50	75	100
2,200	1,600	2,700	2,800	2,800	2,800
4,000	2,100	4,800	4,900	4,900	4,900
6,700	2,600	6,600	7,100	7,300	7,600
10,500	3,000	7,100	8,300	8,500	9,000
15,600	3,300	7,800	9,200	9,700	10,100

Reconnaissance cost estimates were made for several heights of dams at the Coyote Creek Dam site, for a diversion dam on Big Canyon Creek, and for the four sizes of diversion conduits. The diversion dam was assumed to be a concrete overpour type, 10 feet in height. The diversion conduit would extend about five miles in a southeasterly direction from the diversion dam to Coyote Creek Reservoir. About 1,800 feet would be by inverted siphon and the remaining portion would be by canal. A rolled earthfill structure with 3:1 upstream and downstream slopes was used to estimate costs for all heights of Coyote Creek Dam.

The capital cost of the project would range from about $600,000 to $3,500,000, depending on height of structure and size of conduit. It was found that the least costly water would be produced with a diversion capacity of 25 cubic feet per second for the smaller sizes of reservoir and with a diversion capacity of 100 cubic feet per second for the larger sizes of reservoir. A summary of the estimated total capital costs, average annual costs, and unallocated unit costs of water for various sizes of dam and reservoirs, including the Big Canyon Creek diversion dam and conduit, are presented in Table 33. A discussion of the effect of allocating costs is presented in the portion of this chapter dealing with Dry Creek Dam and Reservoir.

TABLE 33

SUMMARY OF RECONNAISSANCE ESTIMATES OF COSTS AND YIELDS FOR COYOTE CREEK DAM AND RESERVOIR

(Including Big Canyon Creek Diversion Works)

Height of dam above stream bed, in feet	Normal water surface elevation USGS datum, in feet	Storage capacity in acre-feet	Estimated firm annual yield, in acre-feet	Cost of dam, reservoir, and diversion works: Capital cost, in millions of dollars	Cost of dam, reservoir, and diversion works: Average annual cost, in thousands of dollars	Estimated average annual unit cost of water at dam 1/: Per acre-foot of firm annual yield, in dollars	Estimated average annual unit cost of water at dam 1/: Per acre-foot of incremental firm annual yield, in dollars
With diversion capacity of 25 cubic feet per second							
80	1,070	2,200	2,800	0.6	30	11	
100	1,090	4,000	4,800	0.9	43	9	7
120	1,110	6,700	6,600	1.4	69	10	14
140	1,130	10,500	7,100	2.2	109	15	80
160	1,150	15,600	7,800	3.3	169	22	86
With diversion capacity of 100 cubic feet per second							
80	1,070	2,200	2,800	0.8	40	14	
100	1,090	4,000	4,900	1.1	53	11	6
120	1,110	6,700	7,600	1.6	79	10	10
140	1,130	10,500	9,000	2.4	118	13	28
160	1,150	15,600	10,100	3.5	179	18	55

1/ Based on unallocated costs. If flood control, recreation, or other purposes are included, a portion of these costs may reasonably be expected to be allocated to the other functions of the reservoir. The degree to which these costs might be chargeable to such functions cannot be determined until final project formulation and design are completed.

Enlarged Detert and McCreary Dams and Reservoirs

Detert Dam is located in Lake County on Bucksnort Creek about five miles east of Middletown in the southeasterly portion of the Guenoc land grant. The original dam was completed in 1927, had a height of 30 feet above stream bed, a crest length of about 1,000 feet and created a storage capacity of about 1,150 acre-feet. The dam was built by farm labor at a cost, not including farm labor, of about 48,000 dollars. A few years later the dam was raised 2 feet to increase the storage capacity to 1,700 acre-feet.

The drainage area above the dam is 10.6 square miles and produces an estimated mean annual runoff of about 13,900 acre-feet. Although in most years the conserved waters from this reservoir have been sufficient to irrigate an area ranging from 700 to 900 acres, the firm annual yield is estimated to have been 1,700 acre-feet, an amount sufficient to irrigate an area of only 500 to 600 acres. Recently, to augment this supply, the present owners constructed an earthfill dam at the lower end of McCreary Lake to provide additional storage capacity to effect a greater degree of conservation of excess flows of Bucksnort Creek. McCreary Dam has a maximum height of about 13 feet and, with flashboards installed on the spillway crest to an elevation of 976 feet, forms a reservoir with a storage capacity of about 2,200 acre-feet. It is estimated that Detert and McCreary Reservoirs, with a combined 3,900 acre-feet of storage capacity are capable of supplying a firm annual yield of about 3,400 acre-feet when operated coordinately.

A net area of about 1,200 acres of irrigable land lies within the boundaries of the 2,200 acre potential Bucksnort Creek service area

24. Detert Reservoir on Bucksnort Creek. The earliest significant surface storage project in the area still supplies water to the Bucksnort Creek area.

25. McCreary Dam and Reservoir. This recently constructed dam at the lower end of the natural McCreary Lake augments the water supply derived from Detert Reservoir.

of these reservoirs. At the time the land use survey was made, only 700 acres were mapped as then being irrigated. These lands were estimated to have a water requirement of about 2,200 acre-feet. If water service were to be provided to the remaining net area of about 500 acres of irrigable lands, the annual supplemental water requirement would be between 900 and 1,300 acre-feet, depending on the type of crops being irrigated. The most likely value of supplemental water requirement was estimated to be 1,100 acre-feet, and when added to the present requirement of 2,200 acre-feet, results in a total future average annual water requirement of about 3,300 acre-feet for this service area.

Inasmuch as the estimated present yield from these two reservoirs exceeds the estimated future water requirements of the service area, no future water development projects are contemplated for this area. However, it is possible that, with the passage of time and experience, the actual water requirements will prove to exceed the estimated requirements and/or the actual reservoir yield will fall short of the estimated yield. In either event, there are sufficient quantities of water originating in Bucksnort Creek to meet the maximum possible water requirements of the service area. This source of water supply could be enhanced by providing additional storage capacity and thereby increase the reservoir yield. It appears that additional storage capacity could be obtained by enlarging either Detert or McCreary Reservoirs at a reasonable cost by raising their respective dams.

26. James Creek dam site and reservoir area--a possible surface storage project to serve a portion of Pope Valley. Waters diverted from nearby Swartz Creek would augment the yield obtainable from this project.

27. Resistant conglomerate along James Creek. This rock type has suitable foundation properties for an earthfill dam.

James Creek Dam and Reservoir

The James Creek dam site is located in Napa County on James Creek about one and one half miles north of the Aetna Springs resort in the center of Section 36, T10N, R6W, MDB&M. Conserved waters from James Creek could be augmented by gravity diverted flows from Swartz Creek and would be best suited for supplying supplemental water for irrigation purposes in the Pope Creek subarea of Pope Valley. Of about 8,200 acres of land in the potential Pope Creek service area, about 200 acres presently receive water service for agriculture and an additional net area of 3,800 acres is considered suitable for irrigated agriculture. These additional lands, under full development, would require from 7,100 to 10,500 acre-feet of water annually, depending on the types of crops being irrigated. The most likely value of future supplemental annual water requirement under full development was estimated to be about 7,700 acre-feet, and when added to the estimated present requirement of 600 acre-feet, results in a total future average annual water requirement of about 8,300 acre-feet for this subarea. An additional net area of 2,900 acres of irrigable land, located in the Burton-Hardin Creek service area of Pope Valley, is also susceptible to gravity service from James Creek Reservoir, but would require a more extensive distribution system.

A topographic map of the dam and reservoir site was prepared by photogrammetric methods at a scale of one inch equals 300 feet, with a contour interval of 10 feet. Reservoir areas, storage capacities, and required quantities of construction materials for the dam were computed from this map. United States Geological Survey quadrangles with a scale of 1:24,000 with a 40-foot contour interval were utilized to select the location and estimate the cost of the diversion dam and feeder canal from Swartz Creek. Location of the James Creek dam and reservoir site and a possible feeder canal from Swartz Creek is shown on Plate 5. The stream bed elevation at the dam site is about 720 feet, United States Geological Survey datum.

Based on a brief geologic reconnaissance, the James Creek dam site appears to be suitable for an earthfill structure of moderate height. Topographic limitations would require the construction of two dikes. The main dam, the east dike, and the east half of the west dike would be founded on conglomerate, sandstone, and shale of Cretaceous age. The west half of the west dike would be founded on silica carbonate rock of the Franciscan group.

In general, foundation preparation for the main dam would include stripping of from 3 to 8 feet of soil, slopewash, and weathered rock. Stripping in the channel would include about 10 feet of alluvium and 2 feet of rock. Moderate stripping of soil, weathered rock, and alluvium would be required for the two dikes.

The spillway should be capable of safely passing an inflow flood with a peak discharge of about 7,000 second-feet. A lined chute spillway through the ridge between the main dam and west dike would have a suitable foundation.

The Swartz Creek diversion dam site, located in Section 11, T9N, R6W, at the mouth of a steep walled canyon, appears to be suitable for a low concrete structure. Stripping of about 15 feet of alluvium would be required in the channel section with moderate stripping of broken shale and slide material from the abutments.

The alignment of the feeder canal would be partially in alluvium and partially in serpentine, shale, and sandstone of Jurassic and Cretaceous age. The 2.8 miles of conduit would include 3 siphons totaling about 1,600 feet in length and would be founded in shale or serpentine which might require spread footings.

There are no records of runoff for the 10.0 square mile area tributary to the James Creek dam site nor for the 5.9 square mile area tributary to the Swartz Creek diversion dam site. However, it is estimated that mean annual runoff from the areas would be 13,700 and 8,000 acre-feet, respectively. Estimates were made of the amounts of water susceptible to diversion from Swartz Creek for four sizes of conduits: 25, 50, 75, and 100 second-feet, respectively. Mean daily flow at the diversion site was assumed to occur in a similar pattern to recorded daily flow of Kelsey Creek and in direct proportion to the ratio of the estimated mean annual runoff of Swartz Creek to Kelsey Creek, at the United States Geological Survey stream gaging station near Kelseyville. The estimated minimum, mean, and maximum annual amounts of water that could be diverted by the four sizes of diversion conduits are presented in the following tabulation:

Conduit capacity, in cubic feet per second	Estimated annual quantities of divertible water, in acre-feet		
	Minimum	Mean	Maximum
25	1,400	4,100	7,200
50	1,400	5,200	10,400
75	1,400	6,000	12,500
100	1,400	6,500	14,200

Yields for various sizes of reservoirs were determined by semi-annual operation studies utilizing estimated divertible water from Swartz Creek combined with the estimated runoff of James Creek. The resultant yields of James Creek Reservoir are presented in Table 34.

TABLE 34

ESTIMATED FIRM ANNUAL YIELD OF JAMES CREEK RESERVOIR

Reservoir storage capacity, in acre-feet	Estimated firm annual yield, in acre-feet				
	With James Creek only	With diversion from Swartz Creek at indicated capacity, in cubic feet per second			
		25	50	75	100
2,700	2,600	3,400	3,400	3,400	3,400
4,600	3,900	5,700	5,700	5,700	5,700
6,900	5,300	7,200	7,200	7,300	7,300
9,700	6,400	8,600	8,700	8,700	8,700
12,800	7,200	9,700	10,100	10,200	10,300

Reconnaissance cost estimates were made for several heights of dam at the James Creek dam site, for a diversion dam on Swartz Creek, and for a 25 second-foot diversion conduit. The diversion dam was assumed to be a concrete overpour type, 10 feet in height. The canal was assumed to be concrete lined. A rolled earthfill structure with 3:1 upstream and downstream slopes was used to estimate costs for all heights of James Creek Dam.

The capital cost of James Creek Dam and Reservoir alone would range from about 1.1 to 3.7 million dollars depending on height of structure. With the addition of a 25 second-foot diversion canal from Swartz Creek, at an estimated capital cost of about $200,000, the total cost of the project would range from about 1.3 to 3.9 million dollars. Increasing the conduit capacity would result in only a small increase in yield and unit cost of water and, therefore, the 25 second-foot size canal is considered most feasible. A summary of the estimated capital costs, average annual costs, and unit costs of water for various sizes of dam and reservoir are presented in Table 35. Unallocated costs for these various dams, including costs for the Swartz Creek diversion works, are presented in Table 36. As with the other cost figures presented for other dams and reservoirs, allocation of costs would reasonably be expected to reduce the estimated annual unit cost of water at the dam if other functions are included.

TABLE 35

SUMMARY OF RECONNAISSANCE ESTIMATES OF COSTS AND YIELDS FOR JAMES CREEK DAM AND RESERVOIR

Height of dam above stream bed, in feet	Normal water surface elevation USGS datum, in feet	Storage capacity in acre-feet	Estimated firm annual yield, in acre-feet	Cost of dam and reservoir: Capital cost, in millions of dollars	Cost of dam and reservoir: Average annual cost, in thousands of dollars	Estimated average annual unit cost of water at dam 1/: Per acre-foot of firm annual yield, in dollars	Estimated average annual unit cost of water at dam 1/: Per acre-foot of incremental firm annual yield, in dollars
70	782	2,700	2,600	1.1	55	21	
80	792	4,600	3,900	1.6	79	20	18
90	802	6,900	5,300	2.1	108	20	21
100	812	9,700	6,400	2.9	144	23	33
110	822	12,800	7,200	3.7	189	26	56

1/ Based on unallocated costs. If flood control, recreation, or other purposes are included, a portion of these costs may reasonably be expected to be allocated to the other functions of the reservoir. The degree to which these costs might be chargeable to such functions cannot be determined until final project formulation and design are completed.

TABLE 36

SUMMARY OF RECONNAISSANCE ESTIMATES OF COSTS AND YIELDS FOR JAMES CREEK DAM AND RESERVOIR

(Including Swartz Creek Diversion Works)1/

				Cost of dam, reservoir, and diversion works		Estimated average annual unit cost of water at dam2/	
Height of dam above stream bed, in feet	Normal water surface elevation USGS datum, in feet	Storage capacity in acre-feet	Estimated firm annual yield, in acre-feet	Capital cost, in millions of dollars	Average annual cost, in thousands of dollars	Per acre-foot of firm annual yield, in dollars	Per acre-foot of incremental firm annual yield, in dollars
70	782	2,700	3,400	1.3	66	19	
80	792	4,600	5,700	1.8	89	16	10
90	802	6,900	7,200	2.3	118	16	19
100	812	9,700	8,600	3.1	155	18	26
110	822	12,800	9,700	3.9	199	20	40

1/ Diversion canal capacity, 25 second-feet.

2/ Based on unallocated costs. If flood control, recreation, or other purposes are included, a portion of these costs may reasonably be expected to be allocated to the other functions of the reservoir. The degree to which these costs might be chargeable to such functions cannot be determined until final project formulation and design are completed.

Upper Maxwell Creek Dam and Reservoir

The Upper Maxwell Creek dam site is located in Napa County in the Maxwell Creek canyon near the southwest side of Pope Valley in Section 35, T9N, R5W, MDB&M. Conserved water could be used for supplying supplemental water by gravity to a portion of the estimated net area of 3,100 acres of irrigable land in the Burton-Hardin Creek service area of Pope Valley. At present, only about 200 acres of these lands are irrigated About 1,000 acres are in nonirrigated grains.

The additional average annual water requirements for these undeveloped irrigable lands would range from about 5,500 to 8,100 acre-feet depending on the type of crops grown. By adding the present water requirement to the most likely value of future additional water requirement, the total future water requirement is estimated to be about 8,300 acre-feet per annum.

The owners of the property upon which the dam and reservoir would be located, Usibelli Coal Mine Company, are planning construction of a 2,000 acre-foot storage reservoir at the site and have applied for water rights to store surplus winter runoff (Applications 18405 and 18647). It is the owner's stated intention to apply the yield from the reservoir to about 1,000 acres of assorted crops in a conjunctive operation with a ground water supply. The estimated average firm annual yield from a reservoir of 2,000 acre-feet capacity would be about 1,300 acre-feet.

The site is suitable for earthfill structures up to 120 feet above the stream bed elevation. The drainage area above the site comprises about 7 square miles and has an estimated mean annual runoff of 3,700 acre-feet. An average firm annual yield of about 2,200 acre-feet could be developed from a reservoir created by this size of dam. However, approximate estimates of costs show that a dam 30 to 40 feet in height would yield the most economical water.

Due to the relatively small yield and limited service area, and to the land owner's interest in the private development of this site, no detailed hydrologic or cost data have been prepared for presentation in this report. The proposed reservoir cannot develop enough yield to satisfy ultimate requirements in the service area. Regardless of place of use of water developed from this site, an additional annual supply of about 6,500 acre-feet would be needed to fully develop the remaining irrigable area.

Walter Springs Dam and Reservoir

The Walter Springs dam site is located in Napa County on Pope Creek about three miles northeast of the town of Pope Valley in the southwest quarter of Section 12, T9N, R5W, MDB&M. This dam was considered by the United States Bureau of Reclamation, in conjunction with the Goodings dam site, as a part of an alternative plan to the construction of Monticello Dam. Construction of a reservoir reduced in size over the one considered by the bureau would permit conservation of winter storm runoff from Pope Creek and would furnish, by pumping, an irrigation supply for the Pope Valley service area.

The service area is topographically divided into two subareas. The Pope Creek and Burton-Hardin Creeks subareas comprise net irrigable areas of about 3,900 and 3,100 acres respectively. As shown in Chapter II, these subareas would have a combined future water requirement of about 16,600 acre-feet per year when fully developed. However, with the construction of Walter Springs Reservoir, some of the irrigable lands would be inundated. The extent of the inundation would depend upon the size of reservoir constructed. From about 155 to 500 acres of irrigable area would be inundated, depending upon the size of reservoir constructed. The inundation would reduce the estimated future water requirements of the service area by about 300 to 1,200 acre-feet per year.

Topography at the dam and reservoir sites is shown on United States Geological Survey quadrangles at a scale of 1:24,000 with contour intervals of 20 feet. These maps were used to determine reservoir areas and storage capacities. Quantities of construction materials were estimated from a topographic map prepared by the Bureau of Reclamation at a scale of one inch equals 200 feet with a contour interval of ten feet.

A geologic reconnaissance survey was conducted at the Walter Springs dam site by the U. S. Bureau of Reclamation. Because their plan envisioned a large dam, up to 175 feet in height, that would actually have been a saddle dam for a dam at the Goodings site, no spillway site geology data were developed by the bureau. A geologic reconnaissance study was made as part of this investigation to determine the most suitable spillway location for dams from 50 to 80 feet in height. Construction of a dam higher than 80 feet, elevation 640 feet, would inundate extensive areas of the irrigable valley lands and thus defeat the purpose of the project to develop the agricultural potential of Pope Valley.

The preliminary geologic reconnaissance of the U. S. Bureau of Reclamation shows that the Walter Springs dam site consists of shale, sandstone, limestone, and diabase breccia of the Franciscan group of Jurassic age. The sedimentary rocks which underlie the channel and right abutment are structurally weak. These sedimentary rocks support 5 to 25 feet of slopewash. Recent alluvium occurs in the channel as benches at the base of the abutment.

Foundation preparations would include stripping of all loose debris and soil on the abutments. Removal of all alluvium in the channel and benches at the base of the abutments appears to be necessary.

The spillway should be capable of safely passing an inflow flood with a peak discharge of about 24,000 cubic feet per second. A lined chute spillway on the left abutment, excavated into diabase breccia, is proposed. Outcrops of fresh rock occur throughout the area and sound rock should exist at shallow depths.

Construction materials are not readily available at the site but material suitable for both pervious and impervious fill are available in Pope Valley, about 1.5 miles away.

Pope Creek enters a confined channel about 1,000 feet below the proposed dam site. Although this canyon appears to afford an excellent site for a concrete arch dam, no attempt was made during this investigation to explore its possibilities. The arch dam could be used as an overpour spillway. If the arch dam is built an earthfill structure would be required in the saddle to the south of the canyon. If further investigation is conducted in this area, the alternative arch dam site should be given consideration before a final decision is reached on the most suitable site for a dam and reservoir to serve Pope Valley.

There are no records of runoff for the 48.4 square miles of drainage area above the Walter Springs dam site; however, it is estimated that the mean annual runoff from the area would be about 35,000 acre-feet. A record of the total runoff from the Pope Valley drainage area will be available for future studies due to installation of a continuous water stage recorder on Pope Creek in December of 1960.

A rolled earthfill structure with 3:1 upstream and downstream slopes with a 30 foot crest width was used to estimate costs. A summary of the estimated capital costs, average annual costs, and unallocated unit cost of water for various sizes of dam and reservoir is presented in Table 37. Cost of pumping the firm annual yield to an elevation of 750 feet was included so that a cost comparison with alternative gravity sources of supply might be made. Capital costs include the estimated cost of a pumping plant sufficient to meet peak irrigation demands for the firm annual yield. Annual costs include the cost of electrical energy necessary to pump the estimated firm annual yield to the 750 foot elevation. From this elevation any part of the service area could be served by gravity flow. The capital cost of the project would range between 800,000 to 2.2 million dollars depending on the height of the dam.

TABLE 37

SUMMARY OF RECONNAISSANCE ESTIMATES OF COSTS AND YIELDS FOR WALTER SPRINGS DAM AND RESERVOIR

Height of dam above stream bed, in feet	Normal water surface elevation USGS datum, in feet	Storage capacity in acre-feet	Estimated firm annual yield, in acre-feet	Cost of dam and reservoir		Estimated average annual unit cost of water at dam 1/	
				Capital cost, in millions of dollars 2/	Average annual cost, in thousands of dollars 3/	Per acre-foot of firm annual yield, in dollars	Per acre-foot of incremental firm annual yield, in dollars
50	599	3,500	3,000	.8	60	20	
60	609	7,250	6,000	1.2	90	15	10
70	619	14,000	9,600	1.7	130	14	11
80	629	24,500	13,700	2.2	170	13	10

1/ Based on unallocated costs. If flood control, recreation, or other purposes are included, a portion of these costs may reasonably be expected to be allocated to the other functions of the reservoir. The degree to which these costs might be chargeable to such functions cannot be determined until final project formulation and design are completed.

2/ Includes capital costs of pumping plant.

3/ Includes annual cost of electrical energy required to pump firm annual yield to 750 feet, USGS datum.

28. Jurassic intrusive rock along Pope Creek about 1,000 feet downstream from Walter Springs dam site. This massive rock would provide a good foundation for any type structure.

29. Goodings dam site and reservoir area on Maxwell Creek in Pope Valley.

Goodings Dam and Reservoir

The Goodings dam site is located in Napa County on Maxwell Creek about 4 miles east of the community of Pope Valley in Section 19, T9N, R4W, MDB&M, as shown on Plate 5. This dam site was considered by the U. S. Bureau of Reclamation in conjunction with the Walter Springs dam site as a part of an alternative plan to the construction of Monticello Dam. A smaller dam at the Goodings site was later included in The California Water Plan as a source of water to serve the lands in Pope Valley. This plan included a diversion of Putah Creek waters from the proposed Middletown Reservoir.

Construction of a reservoir of reduced size would permit conservation of winter storm runoff from Maxwell Creek and would furnish, by pumping, an irrigation water supply for part of Pope Valley. The Burton-Hardin Creeks subarea comprises a net irrigable area of about 3,100 acres. As discussed in Chapter II, this area would have a total future annual water requirement of about 8,300 acre-feet when fully developed. However, with construction of Goodings Reservoir from 300 to 700 acres of irrigable lands would be inundated, depending upon the size of reservoir constructed. The reduced acreage would eliminate from 800 to 1,900 acre-feet of the estimated future water requirement, leaving an ultimate requirement of from 6,400 to 7,500 acre-feet per year.

The recreational potential of Goodings Reservoir would be small since the relatively flat topography of the area will tend to cause mud flats as the reservoir fluctuates during the irrigation season. Its close proximity to Lake Berryessa would also tend to limit its recreational potential.

Topography at the dam and reservoir site is shown on United States Geological Survey quadrangles at a scale of 1:24,000 with a contour interval of 40 feet. Reservoir areas and storage capacities were determined from a plane table survey map prepared by the Department of Water Resources in 1956 at a scale of one inch equals 1,000 feet, with a contour interval of 25 feet. A U. S. Bureau of Reclamation topographic map, at a scale of one inch equals 200 feet with 10-foot contour intervals, was used to estimate earthwork quantities for the dam.

Studies of Goodings Dam and Reservoir included the evaluation of an alternative site located approximately one mile downstream from the Goodings site. A brief geologic reconnaissance of the lower site indicated that the upper site was more favorable.

Based on a preliminary geologic reconnaissance report of the U. S. Bureau of Reclamation, the Goodings site appears to be suitable for an earthfill dam. Construction of a dam higher than 110 feet, elevation 630 feet, would inundate an extensive area of the irrigable lands in the proposed service area and this was, therefore, the limiting height used in the studies made during this investigation.

The dam site consists of fairly steep, soil covered, abutments and a 100-foot wide channel. Bedrock at the site consists of weakly cemented and interbedded sandstones and mudstone. The bedrock forms an anticline, the axis of which strikes parallel to the stream channel and dips into both abutments.

Foundation preparation under the pervious section should include stripping of all loose soil. Stripping for the impervious section should be carried into fairly fresh, sound bedrock. Foundation grouting probably would be required.

The spillway should be capable of safely passing an inflow flood with a peak discharge of about 16,000 cubic feet per second. A lined chute spillway on either abutment is possible.

Construction materials are not plentiful near the site but the residual soils and slopewash should provide sufficient quantities of material suitable for impervious or semipervious fill. Very limited quantities of pervious fill may be obtained from Recent alluvium in the area. Potential sources of riprap and concrete aggregate were not observed near the site.

There are no records of runoff for the 33.3 square miles of drainage area above the Goodings Dam site; however, it is estimated that the mean annual runoff from the area would be approximately 16,500 acre-feet.

A rolled earthfill structure with 3:1 upstream and downstream slopes with a 30-foot crest width was used to estimate costs. A summary of the estimated capital costs, average annual costs, and unallocated unit cost of water for various sizes of dam and reservoirs is presented in Table 38. Cost of pumping the yield to elevation 750 feet was included in the cost estimates so that a cost comparison with alternative gravity sources of supply might be made. Capital costs include the estimated cost of a pumping plant sufficient to meet peak irrigation demands for the firm annual yield. Annual costs include the cost of electrical energy necessary to pump the estimated firm annual yield to the assumed elevation of 750 feet. From this elevation, the entire service area could be served by gravity flow.

A diversion conduit from Pope Creek into Burton Creek would be a means of increasing the firm annual yield of Goodings Reservoir, and should be considered if further studies of this project are contemplated.

TABLE 38

SUMMARY OF RECONNAISSANCE ESTIMATES OF COSTS AND YIELDS FOR GOODINGS DAM AND RESERVOIR

				Cost of dam and reservoir		Estimated average annual unit cost of water at dam1/	
Height of dam above stream bed, in feet	Normal water surface elevation USGS datum, in feet	Storage capacity in acre-feet	Estimated firm annual yield, in acre-feet	Capital cost, in millions of dollars2/	Average annual cost, in thousands of dollars3/	Per acre-foot of firm annual yield, in dollars	Per acre-foot of incremental firm annual yield, in dollars
60	569	3,000	2,200	0.5	40	18	
							14
70	579	7,000	4,300	0.7	70	16	
							14
80	589	14,000	6,100	1.1	95	16	
							25
90	599	21,500	7,100	1.5	120	17	
							25
100	609	33,000	8,100	1.9	145	18	
							25
110	619	50,500	9,100	2.3	170	19	

1/ Based on unallocated costs. If flood control, recreation, or other purposes are included, a portion of these costs may reasonably be expected to be allocated to the other functions of the reservoir. The degree to which these costs might be chargeable to such functions cannot be determined until final project formulation and design are completed.

2/ Includes capital costs of pumping plant.

3/ Includes annual cost of electrical energy required to pump firm annual yield to 750 feet, USGS datum.

Capell Creek Dam and Reservoir

The Capell dam site is located in Napa County on Capell Creek, about one-half mile south of Capell Valley in Section 20, T7N, R3W, MDB&M. The location of the proposed reservoir is shown on Plate 5. Consideration was given to the construction of a dam and reservoir at Capell Creek dam site for the purpose of conserving surplus waters of Capell Creek for use as irrigation and domestic supplies in the Capell Valley service area. Of the 690 irrigable acres in the potential service area, only 130 acres are presently being irrigated. If water service were provided for the remaining 560 acres, the annual supplemental water requirement would range from about 1,100 to 1,600 acre-feet depending on the types of crops being irrigated. Only about 50 percent of these lands can be served by gravity flow; pumping would be required in order to serve the entire valley. However, to the extent that irrigable lands are used for urban purposes, the requirements for irrigation would be reduced accordingly.

Although basin wide reconnaissance studies for surface storage possibilities were concentrated primarily on projects to serve agricultural needs, the requirements of domestic water users were also investigated. Except for the community of Middletown, the only area within the basin expected to urbanize extensively is the potential recreational and commercial areas around Lake Berryessa.

According to a recent report by the Napa County Planning Commission, the domestic water requirement around the westerly shore of Lake Berryessa, including Capell Valley, could increase to as much as 7,500 acre-feet per year under maximum development. About 4,000 acre-feet of this requirement would be needed in the Capell Valley service area. Whether or not such a saturated degree of development will ever be reached could not be determined during this investigation. In any event, water from Capell Reservoir could be used to meet a portion of that domestic demand.

The close proximity of the proposed reservoir to Lake Berryessa will tend to reduce its recreational value; however, the establishment of a fishery would tend to draw some recreationists to the area.

The Capell Creek dam and reservoir sites are shown on U. S. Geological Survey quadrangles at scales of 1:62,500 and 1:24,000 with contour intervals of 50 feet and 20 feet respectively. These maps were utilized to determine reservoir areas, storage capacities, and quantities of construction materials. The stream bed elevation at the dam site is about 765 feet, U. S. Geological Survey datum.

Two alternative dam sites were considered. An upper site, referred to as Upper Capell, is located approximately one mile upstream from the selected site and a lower site, referred to as Lower Capell, is located approximately 2,000 feet downstream. A brief reconnaissance geologic and cost study of the three Capell sites indicated that the middle site was the best of the three considered.

The Capell Creek dam site consists of a steep rocky left abutment, narrow channel, and a long, narrow topographic bench which forms the right abutment. Bedrock at the site consists of interbedded sandstone and shale, belonging to the Knoxville group. The sediments generally strike parallel to the dam site axis and dip very steeply both upstream and downstream. Foundation preparation would include moderate stripping of soil and weathered rock on both abutments and excavation of alluvial sands and gravels in the channel bottom. Special treatment would be required to control leakage.

The spillway should be capable of passing an inflow flood with a peak discharge of approximately 5,000 second-feet. A lined chute spillway could be placed on the left abutment.

Although construction materials are not plentiful near the site, the residual soils and slopewash should provide sufficient quantities of material for impervious or semipervious fill. Limited quantities of pervious fill may be obtained from the Recent alluvium in the area. Several potential quarry sites, which could provide rock for riprap, exist near the dam site.

There are no runoff records for the 8.3 square mile drainage area above the dam site; however, it is estimated that the mean annual runoff from the drainage area is 4,600 acre-feet.

Yield studies and cost estimates were made for dam heights ranging from 45 to 95 feet with a corresponding range in capacity from 800 to 6,300 acre-feet. A rolled earthfill structure with 3:1 upstream and downstream slopes with a 30-foot crest width was used to estimate costs for all heights of Capell Creek Dam. The capital cost of the project would range from $200,000 to $1,600,000 depending on the height of dam.

A summary of the estimated capital cost, average annual cost, and unallocated unit cost of water for various sizes of dam and reservoir are presented in Table 39. Because water conserved by this reservoir might be used for either irrigation or domestic purposes, annual unit costs of water were estimated on both firm and safe yield bases, since a water deficiency cannot be tolerated in a domestic supply.

TABLE 39

SUMMARY OF RECONNAISANCE ESTIMATES OF COSTS AND YIELDS FOR CAPELL CREEK DAM AND RESERVOIR

Height of dam above stream bed, in feet	Normal water surface elevation USGS datum, in feet	Storage capacity in acre-feet	Estimated firm annual yield, in acre-feet	Cost of dam and reservoir: Capital cost, in millions of dollars	Cost of dam and reservoir: Average annual cost, in thousands of dollars	Estimated average annual unit cost of water at dam1/: Per acre-foot of firm annual yield, in dollars	Estimated average annual unit cost of water at dam1/: Per acre-foot of incremental firm annual yield, in dollars
45	802	800	600 (500)	0.2	12	20 (24)	
							12 (15)
55	812	1,400	1,100 (900)	0.3	18	16 (20)	
							16 (16)
65	822	2,300	1,600 (1,400)	0.5	26	16 (19)	
							37 (37)
75	832	3,400	1,900 (1,700)	0.7	37	19 (22)	
							70 (70)
95	852	6,300	2,500 (2,300)	1.6	79	32 (34)	

1/ Based on unallocated costs. If flood control, recreation, or other purposes are included, a portion of these costs may reasonably be expected to be allocated to the other functions of the reservoir. The degree to which these costs might be chargeable to such functions cannot be determined until final project formulation and design are completed.

* Values in parenthesis are for safe yield operation of the reservoir.

Adams Dam and Reservoir

The Adams dam site is located in Napa County on Eticuera Creek 1,500 feet downstream from the confluence of Adams Creek in the south half of Section 22, T10N, R4W, MDB&M. The stream bed elevation is approximately 445 feet, which is about five feet above the maximum pool elevation of Lake Berryessa. The drainage area above the dam site is approximately 54 square miles and has an estimated mean annual runoff of 17,200 acre-feet. The location of Adams dam and reservoir site is shown on Plate 5.

The Adams dam site was first investigated by the U. S. Bureau of Reclamation as part of an alternative plan to the construction of Monticello Dam. It was later considered in studies made for The California Water Plan by the Department of Water Resources, but was not included as a part of that plan.

Although basin-wide reconnaissance studies for surface storage possibilities were concentrated primarily on projects to serve agricultural needs, the requirements of domestic water uses were also investigated. Except for the community of Middletown, the only other area within the basin expected to urbanize extensively is the potential recreational and commercial areas around Lake Berryessa. In order to supply these areas, which are expected to develop along the perimeter of the lake, alternative sources of water will become important to the local interests involved.

The Adams Reservoir was considered during this investigation as a possible alternative to pumping water directly from Lake Berryessa to supply the needs of future home sites, recreational, and commercial developments around the upper end of Lake Berryessa. According to a recent report by the Napa County Planning Commission, the domestic water requirements around the lake, including Capell Valley, could increase to as much as 7,500 acre-feet per year under full development. Of this amount, about 2,000 acre-feet per year would be required to serve areas around the upper end of the lake.

The recreation potential of the proposed reservoir would probably be limited due to its close proximity to Lake Berryessa; however, the establishment of a fishery should tend to draw some recreationists.

The Adams dam and reservoir site is shown on the Walter Springs 7.5 minute United States Geological Survey quadrangles at a scale of 1:24,000 with a contour interval of 40 feet. Reservoir areas and storage capacities were estimated during previous studies from a similar map. The Adams dam site was mapped topographically by the U. S. Bureau of Reclamation at a scale of one inch equals 300 feet with a 20-foot contour interval. This map was used for dam layout and to estimate earth work volumes.

One alternative to the Adams dam site, referred to as the Zim Zim dam site, was investigated. This site is located approximately 1.4 miles upstream from the Adams site on Eticuera Creek. Preliminary cost estimates indicated that the Adams Reservoir would provide water at a lower unit cost; therefore, the Zim Zim site was not considered further.

Based on a preliminary geologic reconnaissance study made by the U. S. Bureau of Reclamation, the Adams dam site appears to be suitable for the construction of an earthfill structure.

Bedrock at the dam site is sandstone of the Knoxville group. This is more or less massive, weakly cemented, and trends at about right angles to the proposed axis with nearly vertical dip. Special treatment would be required to control leakage.

A boulder conglomerate about 50 feet wide extends from the top of the right abutment. This probably would provide a suitable foundation for the spillway, which should be capable of passing an inflow flood with a peak discharge of about 22,000 second-feet.

Estimated stripping depths would vary from approximately 2 feet on the right abutment to 8 or 10 feet on the left abutment. The canyon floor is relatively clear of any alluvial fill.

Pervious and impervious fill should be available in sufficient quantities from the alluvial deposits along Eticuera Creek upstream from the dam site. Riprap would be available from potential quarry sites in the reservoir area.

Yield and cost studies were made for dam heights ranging from 35 to 135 feet with corresponding capacities of 1,500 to 34,400 acre-feet. Quantities of fill material were based on 3:1 slopes with a 30-foot crest width. The capital cost of the project would range from $70,000 to $1,560,000 depending upon the height of the dam.

A summary of the estimated capital cost, annual cost, and unallocated average unit cost of water for various sizes of dam and reservoirs is presented in Table 40. Because water conserved by this reservoir would be used for domestic purposes, annual unit costs per acre-foot were based on a safe yield basis rather than on a firm yield basis, since a water deficiency cannot be tolerated in a domestic supply.

TABLE 40

SUMMARY OF RECONNAISSANCE ESTIMATES OF COSTS AND YIELDS FOR ADAMS DAM AND RESERVOIR

Height of dam above stream bed, in feet	Normal water surface elevation USGS datum, in feet	Storage capacity in acre-feet	Estimated safe annual yield, in acre-feet	Cost of dam and reservoir: Capital cost, in thousands of dollars	Cost of dam and reservoir: Average annual cost, in hundreds of dollars	Estimated average annual unit cost of water at dam 1/: Per acre-foot of safe annual yield, in dollars	Estimated average annual unit cost of water at dam 1/: Per acre-foot of incremental safe annual yield, in dollars
35	469	1,500	1,000	70	35	3	
							5
55	489	3,400	2,100	170	85	4	
							7
75	509	6,600	3,500	350	180	5	
							6
95	529	12,700	5,500	590	300	5	
							9
115	549	21,700	7,000	920	465	7	
							23
135	569	34,400	8,400	1,560	788	7	

1/ Based on unallocated costs. If flood control, recreation, or other purposes are included, a portion of these costs may reasonably be expected to be allocated to the other functions of the reservoir. The degree to which these costs might be chargeable to such functions cannot be determined until final project formulation and design are completed.

Comparisons of Alternative Surface Storage Projects

The various possible plans for water supply development in the Upper Putah Creek Basin must be considered from the standpoint of individual service areas. In considering alternative plans for supplying water to these service areas, particular attention should be given to the following factors: (1) future supplemental water requirements of potential service areas; (2) the net firm annual yield or amount of new water that would be developed by a particular project compared to that which could be developed by alternative projects; (3) the location and accessability of irrigable areas with respect to a project as compared with alternative projects, where cost and maintenance of a lengthy conveyance system could be a deciding factor in project selection; (4) the capital cost of a given project compared to that of alternative projects; (5) the estimated average annual unit cost of water from a given project compared to that from alternative projects; (6) the average annual incremental unit cost of incremental yield that would be developed from various sizes of structures comprising a given project; (7) payment capacity for water; and (8) benefits to be derived from the various plans for water development.

In the following discussion of alternative projects for individual service areas, primary consideration is given to the unit cost of water derived from the projects, at dam and reservoir sizes consistent with the water requirements, and payment capacity within the service area.

Farm budget analyses on representative crops indicate that payment capacities of vineyard and deciduous orchard crops exceed the expected costs of developing additional water supplies in several localities within the basin. The estimated accomplishments and costs of alternative plans for water development may readily be determined by referring to Plates 6 through 8, which show the relationships between storage capacity, yield, and unallocated unit cost of water.

The relationships shown on these plates are preliminary, intended to show the relative merits of one project over another for various magnitudes of water supply development. Plates 6A and 6B show the capital cost for various capacities of reservoirs in Lake and Napa Counties, respectively. The costs represent the total cost of the dam, land acquisition, road and utility relocation, and site clearing, but do not include costs of installing pumping plants, diversion dams and conduits where such features would be required. Costs of these omitted facilities, however, are reflected in the unallocated average annual unit cost of water from each project. Plates 7A and 7B show the relationships between the storage capacities and firm annual yields of reservoirs in Lake and Napa Counties, respectively. Plates 8A and 8B show the relationships between annual yield and the unallocated unit cost of water from reservoirs in Lake and Napa Counties, respectively, measured at the dam.

The final selection of a project to serve any of the service areas will be influenced by the degree of local interest and the ability to form agencies and finance construction and operation of water development facilities

Collayomi-Long Valleys Service Area

Several alternative plans for development of additional surface water supplies for the Collayomi-Long Valleys service area were studied during this investigation. The most promising of these included Dry Creek Reservoir, Middletown Reservoir, Putah Creek Canyon Reservoir, and Crazy

Creek Reservoir to be operated in conjunction with either the Middletown or Putah Creek Canyon reservoirs. However, Middletown and Putah Creek Canyon Reservoirs alone are not considered as true alternatives for all levels of development. For example, if an annual yield of greater than about 6,000 acre-feet is desired, it would be necessary to include an off-stream storage reservoir on Crazy Creek because of the previously discussed height limitation at the Middletown and Putah Creek Canyon sites.

During the past few years there has been active local interest in development of an additional water supply for a portion of this area by the Middletown County Water District. The District boundaries are delineated on Plate 2. At present, the District comprises a total area of about 6,300 acres, but includes only about 56 percent of the irrigable lands in the Collayomi-Long Valley service area. These irrigable lands are estimated to have an average annual water requirement of about 6,000 acre-feet under full development. The Community of Middletown is not included within the District boundaries. The entire Collayomi-Long Valley service area was estimated to have a net irrigable area of about 4,700 acres and, when fully developed, to have an average annual water requirement of about 11,000 acre-feet. The amount of new water supplies needed would be between 8,700 and 11,000 acre-feet per year depending on the magnitude of the present deficiency in water supply.

The Dry Creek Reservoir would be capable of supplying the estimated future water requirements of the area, but at an estimated cost in excess of $20 per acre-foot. An annual yield of about 6,000 acre-feet would cost between $17 and $18 per acre-foot. For annual yields greater than 6,000 acre-feet, the unit cost of water can be substantially reduced by diverting water from St. Helena Creek. Combined firm annual yields ranging from 8,000 to 11,000 acre-feet can be obtained from these facilities for about $16 per acre-foot.

Plans for additional water supply development with the objective of serving the entire Collayomi-Long Valleys service area, including Middletown, appear to be in the best interest of the area. In this respect, it might be advantageous to consider staging the construction of Dry Creek Reservoir and the St. Helena diversion works. Under this concept, a reservoir with a storage capacity of 8,500 acre-feet might be constructed initially at an estimated capital cost of about $2.6 million. This reservoir would provide an estimated firm annual yield of about 7,700 acre-feet at an estimated unit cost of about $18 per acre-foot. At such time as demands for water exceed this yield, the St. Helena diversion works with a capacity of 25 second-feet could be constructed at a cost of about $0.4 million. These works would increase the firm annual yield to a total of about 10,000 acre-feet and would reduce the overall unit cost of water to about $16 per acre-foot for the benefit of all concerned.

Referring to Plate 8A, it can be seen that reservoirs at either the Middletown or Putah Creek Canyon sites, in conjunction with off-stream storage on Crazy Creek, could develop sufficient quantities of water to meet the full requirements for this service area at a unit cost of about $11 per acre-foot at the respective dams. However, there appears to be many more problems involved which could not be fully evaluated during this reconnaissance investigation. For example, problems of design and resultant cost of the control structure between the main and off-stream storage reservoirs are not known to any degree of accuracy. Detailed studies were not made of the problems of dewatering the two separate reservoirs at low stages nor of costs of required pumping and conveyance systems to deliver the water to the service area. Very rough approximations indicate that the unit cost of water delivered to the service area, including pumping costs, would be on the order of $15 or $16 per acre-foot. Therefore, there would be no clear-cut cost advantage favoring either of the downstream reservoirs.

In addition to cost considerations, much of the land that would be inundated by Crazy Creek and the upper reaches of either Middletown or Putah Creek Canyon Reservoirs is either presently developed or is capable of being developed to a much higher degree than lands that would be inundated by Dry Creek Reservoir. The recreational potential is greater at Dry Creek Reservoir than at Middletown, Putah Creek Canyon, or Crazy Creek Reservoirs. It, therefore, appears that construction of a reservoir on Dry Creek, augmented by a diversion from St. Helena Creek, would be the most desirable source of surface water to meet the estimated future water requirements in the Collayomi-Long Valleys service area.

It was stated in Chapter IV, that there is a possibility for increased ground water development in certain parts of the Collayomi-Long Valleys service area. This may make possible the coordinate and conjunctive operation of Dry Creek Reservoir and ground water storage capacity.

Although the magnitude and frequency of historic flooding of Dry Creek was not studied during this reconnaissance investigation it might be desirable to provide some flood control storage in Dry Creek Reservoir in view of the expected future growth of Middletown.

All of the foregoing factors should be considered in future feasibility studies involving the Dry Creek site, so as to provide the greatest benefits to the greatest number of people in the Collayomi-Long Valleys service area.

Coyote Valley Service Area

The Coyote Valley service area is advantageously located below several of the major tributaries of Putah Creek, with the main stream flowing through the center of the valley. The area contains about 2,300 net irrigable acres which, under full development, would have an average annual water requirement of about 5,400 acre-feet. The amount of new water supplies needed would be between 4,000 and 5,400 acre-feet per year depending on the adequacy and reliability of the present sources of supply.

Three possible reservoirs should be considered as potential sources of additional surface water supplies to meet the future demands for water in this area. These are Middletown Reservoir, Putah Creek Canyon Reservoir, and Coyote Creek Reservoir, with a 25 second-foot diversion conduit from Big Canyon Creek.

Any of the three sources could meet future demands for water in the area. The unit cost of water from Putah Creek Canyon Reservoir would exceed that from either Middletown or Coyote Creek Reservoirs. Although reconnaissance estimates of unit cost of water derived from Middletown Reservoir are slightly less than that derived from Coyote

Creek Reservoir, these two reservoirs must be considered competitive pending more thorough design and cost studies. This is particularly true since Coyote Creek Reservoir has a greater potential for outdoor water-associated recreation than Middletown Reservoir. The capital cost for either of these projects was estimated to be in the neighborhood of 1.0 million dollars and the unit cost of water was estimated to range from $8 to $9 per acre-foot.

However, as in the case of the Collayomi-Long Valleys service area, there is a possibility for increased ground water development in the central portion of Coyote Valley. It might be possible to develop ground water in sufficient quantities to meet the entire future water requirements of the area. In any event, future feasibility studies for water development should consider the possibility for coordinate and conjunctive operation of surface and ground water sources as well as the recreational aspects of these reservoirs.

Collayomi, Long, and Coyote Valleys Service Area

The possibility of combining the service areas of Collayomi, Long, and Coyote Valleys, and supplying the entire area from one large reservoir project was given consideration. The total combined service area water requirement would be about 16,400 acre-feet per year. The total amount of new water needed would be between 12,700 and 16,000 acre-feet per year depending upon the adequacy and reliability of presently developed water supplies in meeting present water requirements.

Putah Creek Canyon Reservoir, with off-stream storage on Crazy Creek, could meet these requirements at a unit cost of water of from $10 to $11 per acre-foot. The additional cost of pumping and conveying water to the Collayomi-Long Valleys service area would increase the unit cost of water to $15 or $16 per acre-foot, or about the same cost that would apply to water taken from a Dry Creek Reservoir. Thus, there would be no advantage over the Dry Creek Project for that area. Furthermore, because surface water could be developed for use in Coyote Valley for $8 or $9 per acre-foot from the smaller independent reservoirs, such a large combined project would be a disadvantage to that area. Therefore, a large project for serving the entire Collayomi, Long, and Coyote Valley does not appear to be justified.

Pope Valley Service Area

The Pope Valley service area is topographically divided into two subareas--the Pope Creek subarea and the Burton-Hardin Creeks subarea. Four possible reservoirs should be considered as potential sources of supply to meet the future demands for water in this valley. These are James Creek, Walter Springs, Upper Maxwell, and Goodings Reservoirs. In some respects these sources should be considered as alternatives and in other respects they should be considered as component features of an integrated system for serving the entire valley. For example, for annual yields up to about 9,000 acre-feet, the James Creek, Walter Springs, and Goodings Reservoirs may be considered as alternatives. However, because the future requirements of both subareas exceed 9,000 acre-feet, it becomes obvious upon examination of Plate 8B that either a large reservoir at the Walter Springs site or a combination of two or more reservoirs must be considered if full development of the area is to be achieved.

The Pope Creek subarea was estimated to have an average annual water requirement of about 8,300 acre-feet when fully developed. The alternative projects considered as possibilities in meeting this requirement are James Creek Reservoir, with a 25 second-foot diversion conduit from Swartz Creek, and Walter Springs Reservoir. Construction of James Creek Reservoir without the Swartz Creek Diversion would not satisfy the full requirements of the area and water derived therefrom would be more costly than that derived with the diversion conduit.

For annual yields up to about 6,000 acre-feet Walter Springs Reservoir and James Creek Reservoir, with diversion from Swartz Creek, may be considered competitive. After construction of such facilities the unit cost of water would be between $15 and $16 per acre-foot. Above this level of development, the unit cost of water derived from these two sites diverges rather rapidly. Unit cost of developing sufficient yield to meet the total future annual requirement of 8,300 acre-feet for this subarea would be between $14 and $15 per acre-foot at the Walter Springs site whereas it would be between $17 and $18 per acre-foot at the James Creek site. These costs appear to be within the range of payment capacity of orchard and vineyard crops grown in this area.

The Burton-Hardin Creek subarea was estimated to have an average annual water requirement of about 8,300 acre-feet when fully developed. The alternative projects considered as possibilities in meeting this requirement are Goodings and Walter Springs Reservoirs. Both projects would require considerable pumping. Although not considered as an alternative, private interests are planning to build a small dam and reservoir at the Upper Maxwell Creek site. If this reservoir is built as planned, about 1,300 acre-feet of the requirements in this subarea would be satisfied and the yield needed from Walter Springs or Goodings Reservoir would be reduced accordingly.

For annual yields up to about 6,000 acre-feet Walter Springs and Goodings Reservoirs may be considered competitive. At this level of development the cost of water would be between $15 and $16 per acre-foot. Above this level of development, the unit cost of water derived from these two sites diverges rather rapidly. For a yield of 8,300 acre-feet, the unit cost would be between $14 and $15 per acre-foot at the Walter Springs site and about $18 per acre-foot at the Goodings site.

Unit cost of water is not the only consideration in selecting a plan for water development. Both the Walter Springs and Goodings Reservoirs would require extensive pumping while deliveries from James Creek Reservoir would be by gravity. Even though cost figures were intended to reflect this difference, a gravity supply is often more attractive from a simplicity, reliability, and maintenance viewpoint. Also, both the Walter Springs and Goodings Reservoirs would inundate a sizable portion of the irrigable lands within their respective service areas, while inundation of irrigable lands by James Creek Reservoir would be negligible.

The relative amounts of this inundation for Walter Springs and Goodings Reservoirs are shown in the following tabulation:

Comparison of Areas Inundated for Various Levels of Development

Name of reservoir	Firm annual yield, in acre-feet	Approximate storage capacity, in acre-feet	Approximate area inundated, in acres	
			Total	Net irrigable
Walter Springs	6,000	7,300	500	150
	7,000	8,900	600	200
	8,000	10,700	700	300
	13,700	24,500	1,400	500
Goodings	6,000	13,400	700	300
	7,000	21,400	1,000	500
	8,000	32,300	1,400	700

From a viewpoint of unit cost of water and area inundated it would appear that the Walter Springs site is the most favorable alternative for either the Pope Creek or Burton-Hardin subareas. However, Walter Springs Reservoir would be centrally located and would be capable of developing a much larger yield than that needed for the individual water requirements of either of these subareas. Therefore, it must be considered as a possible single source in serving virtually the entire Pope Valley service area as well as an alternative to James Creek or Goodings Reservoir. The largest size of reservoir studied would produce an estimated firm annual yield of almost 14,000 acre-feet at an estimated unit cost of only $12 or $13 per acre-foot. It would inundate a total area of about 1,400 acres, of which only about 500 acres are irrigable. The estimated capital cost of this dam and reservoir, including a pumping plant capable of lifting the water to an elevation of 750 feet, U.S.G.S. datum, is about 2.25 million dollars.

It appears, therefore, that the Walter Springs dam and reservoir is the most favorable project for supplying future water needs in Pope Valley. A privately developed reservoir on Upper Maxwell Creek would be compatible with development at the Walter Springs site. In addition to a detailed design and cost study of the dam and reservoir, a thorough study of the required distribution system costs, project benefits, and availability of funds would be necessary to fully determine the economic justification and financial feasibility of this project. Since the reservoir would be located in a position where it would intercept a large amount of the irrigation return flow, the reservoir yield would be increased but the quality of the water would be lessened. For this reason, a thorough study of the water quality aspects should precede final selection of a project for this area.

Development of additional water supply projects in Pope Valley will depend, in large measure, upon the zeal of local residents in forming an active local agency for the purpose.

Lake Berryessa and Capell Valley Service Areas

These two potential service areas are discussed as a unit. Both could be served by pumping from Lake Berryessa. Two other sources for serving portions of these areas are Capell Creek and Adams Reservoirs.

The magnitude of future water requirements for these areas has not been determined with any degree of certainty. It was estimated that if lands in Capell Valley were primarily devoted to irrigated agriculture, the total future requirement would be about 1,400 acre-feet per year. However, in a recent water right application, the U. S. Bureau of

Reclamation, in behalf of Napa County, has filed for 7,500 acre-feet per annum for municipal and domestic purposes to be used within a gross area of about 40,000 acres bordering Lake Berryessa. It is believed that of this amount, about 4,000 acre-feet were to be used in Capell Valley and 3,500 acre-feet along the westerly shore of Lake Berryessa.

A supplement to the application, states that "the point of diversion for quantities applied for shall be considered as Monticello Dam, although physical works, at the discretion of the County of Napa, may be located on the banks of the reservoir as the use of water may dictate as developed".

Capell Creek Reservoir was studied as a possible alternative to pumping water directly from Lake Berryessa for use in Capell Valley. The estimated full annual irrigation requirement of 1,400 acre-feet in Capell Valley could be developed at this site for an estimated $16 per acre-foot. Estimates were not made of the cost of pumping and conveying water from Lake Berryessa. However, cost of pumping water from Berryessa to the Capell Valley area would be substantial because the static pump lift would range from about 360 to 600 feet depending on the level of the lake. In selecting a source of additional water supply further consideration should be given to both alternative sources.

Adams Reservoir was studied as a possible alternative to pumping water directly from Lake Berryessa for use around the upper end of the lake where about 2,000 acre-feet of the previously mentioned annual requirement of 3,500 acre-feet would be needed. Of the plans studied, this reservoir was estimated to be capable of developing the least costly water in the basin. A safe annual yield of 3,500 acre-feet was estimated to cost about $5 per acre-foot at the dam. However, the cost of the required distribution system probably would be of considerable magnitude.

Estimates of cost of pumping water from Lake Berryessa to serve this area were not made. However, according to the U. S. Bureau of Reclamation's operations studies of Monticello Reservoir, the water surface of the lake, during a prolonged period of drought, can be expected to fluctuate from a maximum elevation of 440 feet to a minimum elevation of 253 feet, U.S.G.S. datum. Pumping during low water stages would pose problems of considerable magnitude. The location of Adams Reservoir would be advantageous in serving areas around the upper end of Lake Berryessa, where the lateral distance involved in the fluctuation of the water surface of the lake would be at a maximum.

A detailed cost study of these two alternatives should be made before selecting a plan for securing additional water supply for the area. The cost of the required distribution system may well be the deciding factor.

CHAPTER VI. POSSIBILITIES FOR FINANCING WATER DEVELOPMENT PROJECTS

The extent and rate of water development in the Upper Putah Creek Basin will be controlled by the ability to secure financing for water development projects. In order to determine the sources of funds available to finance a water development project, it is necessary to have a specific construction proposal for the lending agency to consider. All lending agencies limit the degree of risk they are willing to assume and the purposes for which they will lend money. The test of financial feasibility is, in essence, an examination of the willingness and ability of the borrower to repay the costs. While such an examination is beyond the scope of this bulletin, an appraisal of some of the potential sources of financing is appropriate. The potential sources of money are private, state, and federal; some projects may involve all three.

Private Financing

The type and extent of private financing appropriate to any specific project depends upon the scale and nature of the project. For example, in some cases, individual wells can be financed directly by the owner without recourse to any lending agency, while it is very seldom that larger scale projects such as dams and reservoirs can be financed by this means. In the case of projects constructed by organized water districts and cities, capital expenditure programs for water resource development of relatively small magnitude are often financed through current taxes and water sales. However, larger scale development programs, in nearly all instances, are financed by the issuance and sale of either general obligation or revenue bonds. General obligation bonds are backed by the full faith and credit of the issuing agency. Repayment is guaranteed by the revenue from the project, plus the taxing power and all sources of revenue of the issuing agency; whereas revenue bonds are repaid by revenues from the specific project for which the bonds were issued.

Bonding Capacity

In general, agencies that would have a direct and overlapping debt, including the cost of the project, of less than about 25 percent of their assessed valuation, can expect to sell bonds at a reasonable interest rate. When outstanding indebtedness exceeds 25 percent, interest rates tend to rise. If the indebtedness becomes great enough the bonds become unsalable. In general, revenue bonds may involve a higher risk and may be expected to bear somewhat higher interest rates than general obligation bonds. The bonding capacity for most areas in the Upper Putah Creek Basin will be limited because their assessed valuations are relatively low.

State Financial Assistance

State financial assistance to local water development projects may be available under the Davis-Grunsky Act in the form of loans or grants or both. Under certain circumstances, the State may participate directly in the project.

State Participation

The State may participate in the construction of a project if it appears desirable in the public interest to construct a larger project than required to supply the needs of the local agency proposing development. Such might be the case where an agency proposes to build a small dam and reservoir at the only site well suited for a larger structure to serve additional potential water users, and where construction of the larger project would be mutually beneficial to all parties concerned. In such a situation, the State may take part in planning, designing, constructing, operating, and maintaining the project, and may finance those costs of the project in excess of the cost necessary to meet the requirements of the agency planning the smaller structure. Legislative authorization and specific appropriation of funds are required for State participation.

Loans

The Department of Water Resources, with the prior approval of the California Water Commission, may lend up to 4.0 million dollars for any one project. The project must be primarily for domestic, municipal, agricultural, or industrial purposes, and the loan is limited to that portion of the project that cannot be financed from other sources on reasonable terms. Loans may be made in excess of 4.0 million dollars for projects authorized by the Legislature. The loans bear interest at the same rate as the net interest cost on the last sale of State general obligation bonds prior to the filing of the loan application. However, if the State rate is not a multiple of one-quarter of one percent, the rate to be charged would be the next even one-quarter percent above the State rate. On this basis, interest rates on loans during 1960-61 would have approximated 4 percent per annum. The principal and interest of these loans must be repaid within a maximum period of 50 years. When justified, a delay in payment on the principal of such loans may be authorized to allow for a period of development not exceeding 10 years.

During the 1961 Legislative session, the Davis-Grunsky Act was amended to provide financial assistance to public agencies for the preparation of feasibility reports on proposed water development projects which had obtained preliminary determination of eligibility from the Department of Water Resources. Loans for feasibility reports may be made up to $25,000 provided funds cannot be obtained from other sources on reasonable terms. Such loans, with interest, must be repaid within 10 years, even if the project is found to be infeasible.

After feasibility has been determined and the application is approved, the cost of preparing the detailed construction designs and specifications can also be covered by the loan for the project.

Grants

Grants may be made for that portion of the cost of a dam and reservoir properly allocated to recreational functions of statewide interest, or to the enhancement of fish and wildlife resources. These functions must be incidental to the primary purposes of the project but cannot be the primary purpose. Up to $300,000 may be obtained through the Department of Water Resources, with the approval of the California Water Commission. Larger grants require authorization by the Legislature. These grants are limited to costs allocated to the dam and reservoir. No grant is authorized if the project does not include a dam and reservoir. The cost of the onshore recreational facilities required for recreational development may not be covered by the grant.

Federal Programs

Various forms of federal financing are available for local water development project assistance. The most significant forms include the Small Reclamation Project Act (Public Law 984), the Watershed Protection and Flood Prevention Act (Public Law 566), and Public Facility Loans (Public Law 345). In the first two acts, provisions are made for non-reimbursable federal contributions for multiple-purpose projects involving flood control and wildlife enhancement.

Small Reclamation Project Act

Public Law 984 (84th Congress) provides assistance to small irrigation projects. This law authorizes the Secretary of the Interior, through the Bureau of Reclamation, to lend a maximum of 5.0 million dollars on a project that does not exceed 10.0 million dollars. The act also authorizes grants up to 5.0 million dollars for flood control, and fish and wildlife enhancement where benefits to the general public welfare can be substantiated. However, the combination of loan and grant may not exceed the 5.0 million dollar maximum for any single project.

Grants may be authorized even though no loan is requested, provided irrigation is the primary project prupose, and the cost of the irrigation project will be borne by the local interests applying for the grant. The irrigation project may provide a domestic, industrial or municipal water supply, as well as commercial power, provided these functions are incidental to the irrigation project.

That portion of the loan properly allocated to irrigation of lands is interest-free except for single ownerships in excess of 160 acres (320 acres for a man and wife under community property laws). Interest must be charged on the reimbursable portion of the project costs chargeable to providing irrigation benefits to lands in excess of 160 acres in a single ownership. Interest must also be charged on the portion of project costs allocated to commercial power, domestic, industrial, and municipal water uses. The interest rate charged on these loans is based on the May market bid quotations on the long-term obligations of the United States Treasury bonds. This rate would apply to all contracts executed during the following fiscal year.

The repayment period will be determined by local economic conditions and must be for the shortest practicable time, but may not exceed 50 years.

Local interests must provide the necessary easements and all costs of lands, and guarantee that it has or can acquire the necessary water rights. Water rights involved in a legal controversy will prohibit the Secretary of the Interior's approval of the loan.

The law further specifies that for projects costing less than 5.0 million dollars the local interests must provide, from sources other than the federal loan, a part of the project construction costs up to, but not to exceed, 25 percent of the reimbursable costs of the project. For projects costing over 5.0 million dollars, the local interests must pay all of the costs over 5.0 million dollars, and must make the contribution that they would have had to make if the project cost had been 5.0 million dollars.

Local interests are responsible for planning, building, operating, and maintaining the system. The Bureau of Reclamation may be consulted to examine the plans and inspect the construction, to determine if the project conforms to bureau standards.

Watershed Protection and Flood Prevention Act

Public Law 566, enacted by the 83rd Congress, as amended by Public Law 1018, authorizes the United States Secretary of Agriculture, through the Soil Conservation Service, to cooperate with local agencies in the planning and constructing of works for improving, protecting, and developing the land and water resources of small upstream watershed areas or subwatershed areas. These works can be for conservation, utilization, and/or disposal of water.

Loans are confined to those areas approved by the Soil Conservation Service for watershed planning. The watershed must not provide a storage capacity of more than 5,000 acre-feet for flood water detention, or have a maximum storage capacity of more than 25,000 acre-feet. The maximum loan authorized by Public Law 566 is 5.0 million dollars.

The interest rate is governed by the average rate paid on the outstanding long-term marketable securities of the United States Treasury. The rate announced at the beginning of the fiscal year will prevail throughout that fiscal year. Loans are scheduled for repayment within the shortest practicable time but may not exceed 50 years. The repayment period begins when the principal benefits begin to accrue to the project.

Eligibility requirements set forth by the Secretary of Agriculture specify that the local interests must be legally empowered to install, maintain, and operate the works of improvements; have insufficient funds and be unable to borrow the funds from a private source at a reasonable interest rate; be able to pay for the loan; have the legal capacity for obtaining, giving security and raising revenues for repayment of the loan; and sponsor, co-sponsor, or agree to participate in a watershed work plan as set up by the Soil Conservation Service.

Public Facility Loans

As authorized under Public Law 345, 84th Congress, the United States Housing and Home Finance Administrator may purchase securities or make loans to public agencies to finance a project essential to public health and welfare where credit is not otherwise available on reasonable terms. Priority is given to applications of communities of less than 10,000 inhabitants for construction of basic public works for municipal purposes. Interest is determined by the Secretary of the Treasury, taking into consideration the current rate of interest of comparable federal obligations.

Types of Organizations

The following discussion pertaining to various types of public districts empowered to deal with matters concerning water--its development, control, and distribution--is intended to point out the importance of selecting the type of organization best suited to the desired purpose. It is not intended to be a complete treatment of this highly complex subject. In any specific case, those interested in forming a water district should consult an attorney who is familiar with the various water districts acts of California.

Existing Agencies

At present, there are two agencies which encompass the entire Upper Putah Creek Basin and which are legally capable of dealing with most water problems of the area. These are the Lake County Flood Control and Water Conservation District and the Napa County Flood Control and Water Conservation District. Both are county-wide agencies.

The purposes and powers of these two agencies are quite similar. Each can provide for control of flood and storm waters of their districts and for conservation of such water for beneficial purposes. In addition, the Napa County District's powers extend to outside watersheds and watercourses flowing into their district. The districts are governed by their respective Boards of Supervisors; however, the Lake County District may delegate its powers to a commission of nine members.

Separate zones may be established for specific projects and/or bonding purposes. However, if a proposed zone of the Lake County District is to include land within a city, then the city must concur in establishing the zone. A provision in the Lake County District's charter permits any chartered or incorporated city to withdraw from the district upon majority vote.

Both districts claim specific powers of eminent domain to establish water projects necessary to achieve their respective purposes. Cooperation with federal agencies is also authorized.

Projects are initiated by investigation of and reports on the zones considered, and through adoption by the respective Boards of Supervisors. The Board of Supervisors of the Napa County District may not proceed with a given action if protests are received from a majority of the registered voters residing within the affected zones. The Napa County Board of Supervisors must suspend action on any project in which holders of real property owning one-half or more of the assessed valuation protest the project.

Financing is through general obligation bonds, subject to the approval of two-thirds of the voters within the zone affected. The bonded indebtedness is confined to the area approving the debt and does not become an obligation of the taxpayers outside the district. Sources of revenue may include the sale of surplus water outside the districts as well as the sales and leases of property. Provisions are also made for an annual ad valorem assessment upon all property in zones for works benefiting such zones or to pay bonded indebtedness as it becomes due.

In addition to these two county-wide districts, there are two active and two inactive smaller organizations which are legally capable of dealing with development and/or distribution of water in the Lake County portion of the basin. The active organizations are the Middletown County Water District (formed January 2, 1959) and the Middletown Soil Conservation District. The inactive agencies are the Lake County Water District and the Middletown County Waterworks District No. 5. There are also several small private water companies throughout the basin, but these probably would not be capable of developing water on a large scale.

The Middletown County Water District boundaries encompass about 56 percent of the irrigable area in Collayomi and Long Valleys. Of the districts discussed, it has the most extensive purposes and powers. In addition to flood control and water conservation, this district may develop and sell power, provide recreation facilities, and drain and reclaim lands. Financing may be through general obligation bonds, revenue bonds, and/or 5-year interest bearing warrants. Revenues are from operation of works for any beneficial purpose, sales and leases of property, and, if insufficient to meet commitments, from ad valorem assessments or from a "water tax".

New Agencies Needed for Water Development

In view of the agencies already existing in the Upper Putah Creek Basin, it appears that prospective water users already have available adequate and capable agencies to initiate the development of water resources and to administer its distribution. The potential service areas such as Collayomi, Long, Coyote, Pope, and Capell Valleys could be zoned for water development and receive water through the Lake and Napa Counties Flood Control and Water Conservation Districts, or establish their own water district, whichever proved to be in their best interest. The Middletown County Water District covers about three-quarters of Collayomi Valley and about one-third of Long Valley, and presumably is capable of developing and serving water in these areas. The remaining area in these two valleys probably could be annexed to this district and thereby could participate in and benefit from water developed by this district.

The extent to which new agencies are needed must be determined by ascertaining the existing agencies' suitability to deal with local water problems and local preference for the method or methods of solving water problems. A major advantage of establishing a county water district rather than a flood control and water conservation district is the wider choice of bonding permitted. The former agency may issue general obligation bonds, revenue bonds, and/or 5-year interest bearing warrants, whereas the latter agency is restricted to general obligation bonds. In cases where it is desired to include recreation facilities as part of a reservoir development it would be necessary to select a district having specific purposes and powers to provide recreation rather than to form a zone within the Flood Control and Water Conservation Districts. Four such types of districts which have authority to provide recreation as a part of water development works are Community Service Districts, County Water Districts, Municipal Water Districts, and Water Conservation Districts. A special district could be created by the Legislature which might add specific powers to those formed under the general act creating the various kinds of districts.

Local Interest in Water Development

Since the U. S. Bureau of Reclamation began construction of Monticello Reservoir in August 1953, there has been an increasing interest in water development in the Upper Putah Creek Basin. This interest received added impetus on February 7, 1957, when the State Water Rights Board issued Decision No. 869 regarding the Bureau applications to appropriate unappropriated water from Putah Creek for the Solano Project. In effect, this decision limits the annual amount of future appropriations of water in the upper basin to 33,000 acre-feet and stipulates that future development must be prior to full beneficial use of Monticello Reservoir water in the Solano Project service area.

This increased interest in water development is evidenced in several ways. It was shown in Chapter II that the demand for water in the upper basin has increased by an average of about 6 percent per year during the 6-year period 1954-1960. This increased demand for water has been accompanied by increased activity in both ground water and surface water development. Numerous water wells -- some successful, some unsuccessful -- have been drilled. Private interests recently enlarged the storage capacity of McCreary Lake to augment the water supply available in the Bucksnort Creek area. Substantial increases in the number of applications to appropriate an increased amount of unappropriated water have taken place. Permits to store appropriated water in the upper basin issued by the State Water Rights Board since February 7, 1957, total in excess of 7,700 acre-feet, whereas the combined storage permits and licenses prior to that date total only about 5,100 acre-feet. In addition, applications since February 7, 1957, to store appropriated water, which are presently pending or incomplete, total an additional 14,000 acre-feet.

Increases in water needs, surface storage, well drilling activities, and the flood of water right applications are not the only indications of interest in water development. Both the Lake and Napa County Boards of Supervisors have repeatedly indicated their interest in future water development in the Upper Putah Creek Basin. It was largely through their efforts that this reconnaissance investigation by the department was undertaken.

The Lake County Board of Supervisors has shown specific interest in development of a reservoir on Dry Creek near Middletown. In 1958 they entered into an agreement with the engineering firm of George S. Nolte to determine the reasonableness of preparing a complete feasibility report in accordance with the requirements of the Small Reclamation Project Act (P.L. 984). At about the same time they entered into an agreement with the U. S. Bureau of Reclamation to conduct a land classification and land use survey in connection with the proposed Dry Creek Reservoir and irrigation system. A conclusion of the Nolte study was that such a project would be economically feasible. Local interests have deferred action on this project awaiting the results of this reconnaissance investigation to see if alternative projects might be more advantageous. Lake County has continued to show active interest. In a letter from the Lake County Flood Control and Water Conservation District to the department dated June 23, 1961, the District indicated that, in cooperation with the Middletown County Water District, plans are being made to go ahead with a dam and reservoir on Dry Creek, and that, under the terms of their water right permit, the project must be under construction by December 1, 1961.

Napa County's primary interests in future water development are presently centered in Pope and Capell Valleys and along the westerly shore of Lake Berryessa. In Pope Valley numerous small, individually built reservoirs and farm ponds have been constructed in recent years. There have been several attempts to develop ground water supplies -- mostly unsucesful. These somewhat uncoordinated efforts provide an insignificant amount of water in comparison to the total future requirements of the area. Recently, private interests have been considering construction of a 2,000 acre-foot reservoir on Upper Maxwell Creek, but progress on this project has been slowed because of extensive water right hearings in November, 1960.

In Capell Valley, several individual attempts to develop ground water have resulted in obtaining limited supplies sufficient only for present domestic and stock watering needs. The only significant surface storage development in this valley is Moskowite Dam and Reservoir, completed in 1951. In recognition of the possibility that both Capell Valley and the area along the westerly shore of Lake Berryessa could develop as residential and commercial areas, the U. S. Bureau of Reclamation, in behalf of the Napa County Board of Supervisors, has applied for water rights in the amount of 7,500 acre-feet per annum, most of which would be pumped directly from the lake. All of these actions in the Upper Putah Creek Basin indicate a keen interest in water development.

CHAPTER VII. CONCLUSIONS AND RECOMMENDATIONS

As a result of this reconnaissance investigation the following conclusions, and recommendations are made.

Conclusions

1. Present water problems in the Upper Putah Creek Basin involve physical, economic and legal factors. However, the foremost problem concerning water development confronting the people of the area is that of time available to appropriate and develop additional water supplies for future needs of the area.

2. Future development of local water resources could be inhibited by the inability to secure appropriative water rights to surface waters. On February 7, 1957, in Decisiion No. 869 the State Water Rights Board ordered that:

> "The permits and all rights acquired or to be acquired thereunder are and shall remain subject to depletions of stream flow above Monticello Reservoir not to exceed 33,000 acre-feet of water annually, by future appropriations of water for reasonable beneficial use within the watershed of Putah Creek above said reservoir; provided such future appropriations shall be initiated and consummated pursuant to law prior to full beneficial use of water within the project service area under these permits."

3. The entire safe annual yield from Monticello Reservoir may be used by 1980, and all but 33,000 acre-feet of this yield may be put to use by 1974. Thus, there remains only 13 to 19 years for the local people of the upper basin to appropriate, develop, and put to use, local water supplies.

4. Limitations imposed by the permits granted under Water Rights Board Decision No. 869 would not apply to lands with rights to pumped ground water applied to beneficial use on lands overlying a ground water basin, or to stream flow depletion caused by natural recharge of

the basin. On the other hand, it is believed that the limitations would apply to extracted ground water used on lands not overlying a ground water basin and to the recharging of the basin by artificial means.

5. Of the 8,100 acres of land presently devoted to crop land in the basin, only 2,600 acres are irrigated. This is a relatively minor degree of development compared to the potential development of more than 28,000 acres of irrigable land.

6. The estimated present mean annual water requirement in the basin is about 8,500 acre-feet, of which, over 95 percent is for irrigated agriculture. The basin experiences a natural water supply deficiency during fall and summer months, but the magnitude and extent of this deficiency in relation to the present water requirement is not known.

7. Irrigation will continue as the dominant water requirement in the basin within the foreseeable future.

8. Payment capacity for agricultural water on representative crops in the basin ranges from about $3 to $6 per acre-foot for irrigated pasture and alfalfa, respectively, to about $20 per acre-foot for deciduous orchard crops, to a high of about $33 per acre-foot for vineyard crops.

9. Future irrigated agriculture of appreciable magnitude will probably be restricted to deciduous orchard and vineyard crops because of the relatively high cost of the potential major water development works in relation to payment capacity for agricultural water.

10. Future residential, commercial, and recreational developments may be induced along the westerly shore of Lake Berryessa and in Capell Valley by the year-round recreational opportunity afforded by the

lake and by its close proximity to Sacramento and the San Francisco Bay Area. These lands could physically support an estimated population of about 60,000 people. Whether or not these lands will ever be developed to their fullest capabilities is not known at this time.

11. The future supplemental water requirement for full development of the presently undeveloped irrigable lands in the selected service areas (which represent 75 percent of the irrigable lands in the basin) is estimated to be about 30,000 acre-feet per year.

12. In cases where residential, commercial, and recreational developments encroach on the irrigable lands in the basin, the water requirement estimated for irrigation should be more than ample. Developments of this type occurring on nonirrigable lands, such as that taking place along the westerly shore of Lake Berryessa, will have water requirements over and above those for irrigation. A thorough appraisal of the rate and magnitude of future demands for water for these types of development was not made during this reconnaissance investigation.

13. Runoff in the Upper Putah Creek Basin is derived principally from rainfall. The estimated mean annual natural runoff originating in the basin is about 348,000 acre-feet, which greatly exceeds all possible future beneficial uses which may reasonably be anticipated in the basin.

14. Runoff is presently developed to a very high degree but only a small amount is available for local use. The present average annual depletion of runoff resulting from use above Monticello Reservoir is about 6,000 acre-feet, while the net safe annual yield from Monticello Reservoir, including release for downstream prior rights, is about 262,000 acre-feet --all to be used outside the upper basin.

15. Surface water supplies within the Upper Putah Creek Basin are generally of good mineral quality except for excessive hardness which may annoy domestic users. Another possible exception occurs in localized areas when high boron concentrations during low flows make the water unsuitable for irrigation on all except the most tolerant crops. Surface storage reservoirs would tend to reduce these problems by mixing and dilution of the more mineralized low flows with the better quality rainfall-fed high flows. Although water quality data on ground water supplies are sparse, it is probable that its mineral character closely resembles that of surface water.

16. The prospects for developing additional ground water in significant quantities throughout the major portion of the watershed are not favorable. There may be exceptions to this probability in Collayomi, Long, and Coyote Valleys, where a substantial portion of the present agricultural water requirements are met from existing wells.

17. Additional water supplies probably could be developed in the Upper Putah Creek Basin, in varying magnitudes at attendant costs but within the range of payment capacities of vineyard and orchard crops, through implementation of any one or a combination of the following plans.

a. Utilization of ground water could be increased in Collayomi, Long, and Coyote Valleys.

b. Dams and reservoirs could be constructed at Dry Creek, Middletown, Putah Creek Canyon, Coyote Creek, James Creek, Walter Springs, Goodings, Capell Creek, or Adams sites.

c. Yield of the Dry Creek and James Creek reservoirs could be augmented by construction of facilities for stream flow diversion from St. Helena and Swartz Creeks, respectively. Construction of these facilities would reduce the unit cost of water delivered from Dry Creek and James Creek reservoirs. Construction of Coyote Creek reservoir would require a diversion from Big Canyon Creek because of the limited runoff at the Coyote Creek site.

d. Yield of the Middletown or Putah Creek Canyon reservoirs could be augmented by construction of an off-stream storage reservoir at the Crazy Creek site. This does not appear to be necessary in view of other possibilities available.

18. The least costly method of developing additional water supplies probably would be through increased utilization of ground water where possible. Present ground water pumpage could possibly be doubled in the Collayomi-Long Valleys and tripled in Coyote Valley. Reliable estimates of the amount and cost of additional ground water which might be developed could not be made during this reconnaissance investigation. Limited data indicate that the yield of wells in these basins is highly variable. Prediction of the total number of wells necessary to meet the needs for supplemental water was impossible because of the limited data available. Nor could any prediction be made of the number of test holes which might have to be drilled in any particular area in order to provide a single satisfactory well.

19. The most promising source of an additional surface water supply for the Collayomi-Long Valleys service area appears to be Dry Creek Reservoir, with an augmented supply from a St. Helena Creek diversion works. Reconnaissance studies indicate that combined firm annual yields ranging from about 8,000 to 11,000 acre-feet could be obtained from these facilities for about $16 per acre-foot. Capital costs for these facilities would range from about 2.4 million dollars to about 3.5 million dollars, depending upon the yield desired. This project could be staged, to a limited extent, by deferring construction of the St. Helena diversion works. Under this concept, initial capital costs could be reduced by about 0.4 million dollars but the initial unit cost of water would be increased by about $2 per acre-foot. These yields and costs were based on a single purpose project.

In addition to water conservation, Dry Creek Reservoir has considerable potential for outdoor recreation and might be planned to provide some flood protection for the community of Middletown. Constructing the reservoir to a somewhat larger capacity, to provide a moderate amount of storage at minimum pool for recreation, would also give added assurance of an adequate water supply during periods of severe drought. The Dry Creek Project might be operated conjunctively with ground water storage, so as to reduce the size and cost of the required surface reservoir and the cost of an extensive distribution system.

Future feasibility studies of the Dry Creek Project should include all of these factors, with the objective of providing the greatest benefits to the greatest number of people in the Collayomi-Long Valleys service area, including the community of Middletown. Such multiple purpose use should result in a lower unit cost of water.

20. Middletown Reservoir and Coyote Creek Reservoir, with a diversion from Big Canyon Creek, appear to be competitive sources of additional surface water supply for the Coyote Valley service area. Reconnaissance estimates indicate that a firm annual yield of approximately 4,000 to 5,400 acre-feet could be obtained from either of these two projects for $8 to $9 per acre-foot. Capital costs for either of these two projects would range from about 0.6 million dollars to 0.9 million dollars depending on the yield desired. Comparable yields from Putah Creek Canyon Reservoir would be more costly than from either of these two reservoirs.

Because Coyote Creek Reservoir has a greater potential for outdoor recreation than Middletown Reservoir it may prove to be the more desirable project of the two. However, the possibility of increased ground water development in Coyote Valley may make possible the coordinate and conjunctive operation of either of these reservoirs with ground water storage. Such operation would reduce the size and cost of the required surface reservoir and the cost of an extensive distribution system.

Future feasibility studies of potential water supply developments for the Coyote Valley service area should include a more detailed appraisal of all of the pertinent factors. Putah Creek Canyon Reservoir and off-stream storage reservoir on Crazy Creek should be eliminated from further consideration.

21. In the Bucksnort Creek area, the estimated firm annual yield of the presently developed water supply from Detert and McCreary Reservoirs is capable of meeting the estimated present and future water requirements of that area. Therefore, no additional facilities should be

contemplated for that area. However, should the actual water requirement exceed the actual yield from these reservoirs, additional yield could be obtained at reasonable cost by enlarging either reservoir.

22. The most promising source of an additional water supply for full development of the Pope Valley service area appears to be Walter Springs Reservoir. Reconnaissance studies indicate that a firm annual yield of almost 14,000 acre-feet could be obtained from this reservoir and pumped to an elevation of 750 feet for about $12 or $13 per acre-foot. Capital cost for this project would be about 2.2 million dollars. Additional development of ground water in significant quantities is not likely in this area.

Should local interests desire to proceed initially with a smaller degree of development, Walter Springs Reservoir, Goodings Reservoir, and James Creek Reservoir, with a diversion from Swartz Creek, would all be competitive on a unit water cost basis. For a firm annual yield of about 6,000 acre-feet, water could be developed for about $15 to $16 per acre-foot. Although unit cost of water from these smaller alternatives would be comparable, capital costs would be about 1.9 million dollars for the James Creek Project and only 1.1 million dollars or 1.2 million dollars for the Goodings or Walter Springs projects, respectively. This difference in capital cost would be offset by the average annual costs because of required pumping costs at the Walter Springs or Goodings sites.

Future feasibility studies of potential water supply developments for the Pope Valley service area should include a statement from the local interests of the desired level of initial development, after which more detailed studies of the appropriate alternatives should be made. Future studies of the Walter Springs Reservoir site should also include the possibilities for construction of a concrete arch dam about 1,000 feet downstream from the site discussed herein.

23. Napa County is presently taking steps to meet anticipated future demands for domestic water along the westerly shore of Lake Berryessa and in Capell Valley by securing water rights to pump directly from the lake. During prolonged periods of drought the water surface of the lake can be expected to fluctuate through wide limits which would induce problems of considerable magnitude when pumping water during low water stages. Estimates of the cost of obtaining water from this source were not made during this reconnaissance investigation, but were made for two alternative sources.

An estimated firm annual yield of 1,400 acre-feet for use in Capell Valley could be obtained from Capell Creek Reservoir for about $16 per acre-foot. Capital costs for this reservoir would be about 0.5 million dollars. There are two problems connected with pumping water from the upper end of Lake Berryessa; (1) the difficulty of designing an efficient pumping plant for the varying water elevations, and (2) the large lateral displacement which takes place for small vertical displacements. The location of Adams Reservoir site would therefore be advantageous in serving areas around the upper end of the lake.

Future feasibility studies of potential water supply for these two areas should include a more detailed study of all of the foregoing factors. Studies of the required distribution system along the lake shore should also be made, since the cost of these facilities may well be the deciding factor in selecting a plan to serve this area.

24. In view of the agencies already existing in the Upper Putah Creek Basin, it appears that prospective water users already have available adequate and capable agencies to initiate the development of water resources and to administer its distribution. However, in order to secure a wider choice of possibilities for financing water development projects or to be able to include recreation as a part of a potential project, certain areas may find it advantageous to form new districts having more extensive powers.

25. There appears to be a keen local interest in future water development throughout the Upper Putah Creek Basin. However, additional information is needed on current views of local interests. This information will be needed before a specific project can be formulated.

26. All possible projects considered in the Upper Putah Creek Basin would be compatible with The California Water Plan and would not preclude water developments in other areas of the watershed.

Recommendations

As a result of this reconnaissance investigation of the engineering, geologic, economic, and legal aspects affecting future water development in the Upper Putah Creek Basin, the following recommendations are made:

1. That, after receiving documented and specific desires of local interests, a more detailed investigation be conducted to determine the economic justification and financial feasibility of specific projects in the upper basin, including the maximum practical extent of further development of ground water occurring in Collayomi, Long, and Coyote Valleys.

2. That a program to collect additional basic hydrologic data at specific locations be initiated immediately to provide a sound basis for more detailed analysis of the more favorable water development possibilities. In particular, stream gaging stations should be installed on streams planned for diversion to off-stream storage reservoirs. A comprehensive ground water level measurement and stream flow percolation determination program in areas deemed suscepitble to additional ground water development should be undertaken.

3. That local interests proceed with development of their water resources as fast as economically possible in order to keep the possibility of loss of right to appropriate presently unappropriated water at a minimum.

4. That local interests continue to appear, and state their interest and present position, at all hearings on water rights affecting the Upper Putah Creek Basin.

5. That plans for further development of the water resources of the Upper Putah Creek Basin be based on the conclusions and recommendations of this investigation and that no further consideration be given to those sites eliminated by these studies.

APPENDIX A

SUMMARY OF

APPLICATIONS TO APPROPRIATE WATER

IN THE UPPER PUTAH CREEK BASIN

APPLICATIONS TO APPROPRIATE WATER
IN UPPER PUTAH CREEK BASIN
AS OF SEPTEMBER 1, 1961

Application Number	Date Filed	Present Owner	Source	Location of Point of Diversion ¼	¼	Sec.	Tp.	R.	M.	Amount and Period of Diversion	Purpose of Use	Status
533	12/13/16	Society of the Divine Word	Unnamed creek tributary to James Creek	SW	SW	32	10N	5W		0.125 cfs	Irrigation, Recreation	License 88
638	4/6/17	Lilian C. Bowler	Putah Creek	proj.		19	11N	6W		1.0 cfs	Irrigation	License 151
1178	2/13/19	Harold W. and Bertha K. Kerrison	Old Rosenboom Mine Tunnel No. 1	SE	SE	25	8N	4W		0.075 cfs	Domestic, Irrigation	License 87
3069	10/9/22	Investment Operating Corporation	Bucksnort Creek	S 1/2		9	10N	6W		5.35 cfs 1100 afa	Irrigation	License 2141
3797	1/14/24	Mary A. Bowcher	Putah Creek	NE	SE	28	11N	6W		0.95 cfs	Irrigation	License 918
4379	12/16/24	Robert Ramsey	Harbin Creek	SW NW	NE SE	20 20	11N 11N	7W 7W		0.14 cfs	Irrigation, Stockwater	License 1015
4889	1/15/26	Investment Operating Corporation	Bucksnort Creek	S 1/2		9	10N	6W		100 afa	Irrigation	License 2142
9574	5/4/39	Don N. Duvall	Unnamed stream tributary to Pope Creek	SW	NE	12	9N	6W		150 afa	Irrigation	License 2947
9695	8/11/39	Adolph C. Haug	Haug Creek	SE	NW	19	9N	5W		0.41 cfs	Power, Irrigation	License 2633
11236	12/11/45	Dick Week	Unnamed stream tributary to Pope Creek	SW	NW	10	9N	5W		180 afa	Domestic, Irrigation	License 4446
11873	5/12/47	Clara L. Mirabile	Capell Creek	NW	NW	33	7N	3W		0.5 afa	Domestic, Stockwater	License 4661
11930	6/10/47	George Moskowite	Unnamed stream tributary to Capell Creek	SE	NE	16	7N	3W		200 afa	Irrigation	License 4327
12596	7/16/48	Norman K. and Dorothy Blanchard	Unnamed stream tributary to Pope Creek	NW	NE	18	9N	5W		8 afa	Domestic, Irrigation	License 3863
12851	12/9/48	Richard Week	Unnamed stream tributary to Pope Creek	SE	NE	10	9N	5W		41 afa	Irrigation, Stockwater	License 3576
13053	4/25/49	Lee and Mary E. Eakle	Hardin Creek	NW	SW	30	9N	4W		0.1 cfs 15 afa	Irrigation	Permit 7764
13341	9/8/49	R. F. and V. W. Kaufman	Washington Creek	Lot 14		2	9N	6W		0.025 cfs	Domestic	License 3595
13543	1/18/50	Fred and Lucille F. Hurlbut	Unnamed stream tributary to Pope Creek	NE	SE	18	9N	5W		7.5 afa	Irrigation	License 4053
13597	2/23/50	Tahoe Keys, Inc.	Pope Creek and an unnamed stream tributary to Pope Creek	NW SW	SE SE	9 9	9N 9N	5W 5W		65 afa	Irrigation	License 4464
13672	4/6/50	George Moskowite	Unnamed stream tributary to Capell Creek	SE	NE	16	7N	3W		100 afa	Irrigation	Permit 8412
13730	5/11/50	Donald F. Ross	Unnamed stream tributary to Burton Creek	NW	SW	20	9N	5W		2.0 afa	Irrigation	License 5445

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13771	6/5/50	Harry I. and Nancy A. Kelly	Unnamed tributary to Bucksnort Creek	NE	NW	8	10N	6W		148 afa	Irrigation, Domestic	Permit 8861
13801	6/19/50	George B. and Ruth V. Heibel	Aetna Creek	SW	SW	1	9N	6W		21.0 afa	Irrigation	License 5877
13834	7/5/50	Edric W. Vredenburg	Troutdale Creek	NW	SW	36	10N	7W		3.0 cfs 1 afa	Recreation, Domestic	Permit 9015
13915	8/23/50	Mayrene Gray	Unnamed creek tributary to Ashbill Creek	SE	SE	19	12N	6W		14.4 afa	Domestic, Irrigation	License 5826
13918	8/24/50	Walter and Alma Priest	Soda Creek	NW	SW	23	8N	4W		200 afa	Irrigation	Permit 8446
14024	10/27/50	Dick Week	Unnamed stream tributary to Pope Creek	SW	NW	10	9N	5W		150 afa	Domestic, Irrigation	License 4447
14391	7/16/51	Gordon R. Kirkpatrick	Burton Creek	NE	NE	19	9N	5W		0.3 cfs	Domestic, Irrigation	Permit 8938
14392	7/16/51	Gordon R. Kirkpatrick	Unnamed creek tributary to Burton Creek	NW	NW	20	9N	5W		16 afa	Irrigation	License 5435
14681	2/15/52	C. F. Maier	Unnamed stream	SE	SE	20	9N	5W		3.5 afa	Recreation	License 5092
14784	4/29/52	Alva A. Dinneen	Collayomi Brook	SW	NE	14	11N	8W		2,500 gpd	Domestic	License 5247
14787	4/30/52	Sarah McInnis	Collayomi Brook	SW	NE	14	11N	8W		4,500 gpd	Domestic	License 5600
14788	4/30/52	Martin J. and Lillian E. Jackson	Collayomi Brook	SW	NE	14	11N	8W		1,800 gpd	Domestic	Permit 9941
14846	6/10/52	Herbert J. Smith	Collayomi Brook	SW	NE	14	11N	8W		1,200 gpd	Domestic	License 5676
14974	8/15/52	Donald F. Ross	Unnamed stream tributary to Burton Creek	NW SW	SW SW	20 20	9N 9N	5W 5W		5,000 gpd	Domestic, Irrigation	License 5446
14995	8/26/52	T. L. Neil	Unnamed stream tributary to Burton Creek	NE	SE	20	9N	5W		10 afa	Domestic	License 5339
15038	10/2/52	United States Corps of Engineers	Putah Creek	SW	NW	24	11N	6W		0.035 cfs	Domestic	License 5382
15164	1/21/53	Dick Week	Unnamed creek tributary to Pope Creek	SW	NW	10	9N	5W		180 afa	Stockwater, Irrigation	Permit 9563
15196	2/13/53	Joe Stern	Unnamed creek tributary to Pope Creek	SW	NW	8	9N	5W		75 afa	Stockwater	License 5985
15258	3/30/53	J. A., K. M., and S. J. Burns	Unnamed creek tributary to Swartz Creek	NW	NE	11	9N	6W		48 afa	Domestic, Irrigation	Permit 9495
15281	4/6/53	H. L. Puge	Unnamed stream tributary to Burton Creek	SE	SW	21	9N	5W		42 afa	Irrigation	License 5806
15312	4/23/53	Estate of William Moskowitz	Unnamed stream tributary to Capell Creek	SW	SW	34	7N	3W		150 afa	Irrigation	Permit 9565
15321	4/29/53	J. Roy Pridmore	Unnamed stream tributary to Capell Creek	SE	SE	8	7N	3W		57.0 afa	Irrigation	License 5555

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15323	4/30/53	W. D. Hammond	Potassium Creek	NE NW	NE NE	1 1	9N 9N	6W 6W		25 afa 30 afa	Irrigation	License 6015
15421	7/21/53	George Moskowite	Unnamed stream tributary to Capell Creek	SE	NE	16	7N	3W		125 afa	Irrigation	License 6026
15568	10/6/53	Walter D. and Alma Priest	Unnamed spring Unnamed stream Soda Creek	SE SE SE	NW NE SE	25 26 26	8N 8N 8N	4W 4W 4W		1,000 gpd 0.05 cfs 0.43 cfs	Domestic, Stockwater, Irrigation	License 5467
15609	11/10/53	George R. Anderson	Putah Creek	NE	SE	33	11N	7W		0.34 cfs	Domestic, Irrigation	Permit 9769
15706	1/28/54	Investment Operating Corporation	Bucksnort Creek	NE *NE *SW *NE	SE SE NW NW	34 34 3 2	11N 11N 10N 10N	6W 6W 6W 6W		1222 afa	Irrigation, Stockwater	License 6334
15784	3/18/54	George P. Belcher	Crazy Creek (underflow)	SW	SW	29	11N	6W		0.67 cfs	Irrigation	License 5333
15934	6/29/54	Tahoe Keys, Inc.	(1) Unnamed stream (2) Pope Creek	NW SW	SE SE	9 9	9N 9N	5W 5W		40.0 afa 0.88 cfs	Irrigation	Permit 9930
16114	10/25/54	Ralph K. Davies	Unnamed spring tributary to Putah Creek	SE	NW	29	11N	7W		500 gpd	Irrigation, Domestic	License 5120
16153	11/29/54	Lillian C. Bowler	Gallagher Creek	SW	SW	17	11N	6W		500 gpd	Stockwater	Permit 10284
16257	3/7/55	George and Anna M. Haus	Unnamed stream	SE	NE	29	9N	5W		12.0 afa	Irrigation, Recreation	Permit 10267
16267	3/10/55	Dick Week	Unnamed stream	SW	NW	10	9N	5W		150.0 afa	Domestic, Irrigation, Stockwater	Permit 11241
16268	3/10/55	Dick and Ann Week	Unnamed spring	NW	SW	2	9N	5W		4000.0 gpd	Irrigation, Domestic, Recreation, Stockwater	License 6046
16488	7/26/55	Joe Stern	(1) Unnamed stream (2) Pope Creek	SW SW	NW SW	8 5	9N 9N	5W 5W		140.0 afa	Irrigation, Stockwater	Permit 11170
16613	9/19/55	John A., Sarah, Joan, and Katherine Burns	Aetna (Star) Creek	NW NW	SE NE	2 11	9N 9N	6W 6W		40.0 afa	Irrigation, Stockwater	Permit 12260
16776	12/8/55	George W. Nunes	N. F. Collayomi Brook	SW	NE	14	11N	8W		3,000 gpd	Irrigation, Domestic	Permit 11299
16922	3/8/56	Madlyn R. Mortara	Collayomi Brook	SW	NE	14	11N	8W		1,800 gpd	Domestic	Permit 11300
16923	3/8/56	Charles L. Lamp	Collayomi Brook	SW	NE	14	11N	8W		700 gpd	Domestic	License 6231
16924	3/8/56	Earle M. & Margaret Hanson	Collayomi Brook	SW	NE	14	11N	8W		650 gpd	Domestic	License 5986
16925	3/8/56	Estate of Burnell Cooley	Collayomi Brook	SW	NE	14	11N	8W		550 gpd	Domestic	License 6311
16960	3/21/56	Clara Abreu and Manuel Abreu	Maxwell Creek	SW	NW	12	8N	5W		14.5 afa	Irrigation, Stockwater	Permit 10999

* Rediversion Points

APPLICATIONS TO APPROPRIATE WATER

IN UPPER PUTAH CREEK BASIN

AS OF SEPTEMBER 1, 1961

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16984	4/3/56	Helen and Emile Grand	Unnamed spring	NE	SE	10	11N	8W		8,100 gpd	Domestic	Permit 10796
17007	4/16/56	Clara and Manuel Abreu	Unnamed stream	NW	SE	1	8N	5W		6.0 afa	Stockwater	Permit 10991
17153	6/25/56	Ernest L. Layton	Soda Creek	NE	NW	21	12N	6W		10,000 gpd	Irrigation, Domestic, Stockwater	Permit 10834
17295	9/25/56	Robert M. and Paul S. Meyerkamp	Unnamed stream	SW	NE	20	9N	5W		12.0 afa	Domestic, Irrigation, Stockwater	Permit 10887
17331	10/19/56	Ralph K. Davies	Bear Canyon Creek	NW *SW	NE SW	36 29	11N 11N	8W 7W		250.0 afa	Irrigation	Permit 11074
17464	2/13/57	Buck L. Handon and Frank W. Hailey	Unnamed stream	SE	NE	26	10N	7W		625 gpd	Domestic	License 6117
17476	2/21/57	Gordon R. Kirkpatrick	Burton Creek	NE	NE	19	9N	5W		20.0 afa	Irrigation	Permit 10923
17555	4/22/57	Lawrence L. and Thelma E. Groteguth	Unnamed stream	NW	SE	22	9N	5W		33.0 afa	Domestic, Irrigation, Recreation, Stockwater	Permit 11119
17557	4/22/57	Allen and Joyce J. Mooney - Emery and Lorine Dennis	Unnamed stream	SE	SE	2	8N	5W		14.0 afa	Domestic, Irrigation	Permit 11107
17690	6/28/57	Lyndon G. Mee	Unnamed stream	NE	SE	32	10N	3W		6.0 afa	Stockwater	Permit 11355
17691	6/28/57	Lyndon G. Mee	Unnamed stream	NW	NE	32	10N	3W		3 0 afa	Stockwater	Permit 11180
17734	7/24/57	Joe Stern	Unnamed stream	SE	SW	6	9N	5W		30.0 afa	Domestic, Irrigation, Recreation, Stockwater	Permit 11249
17823	9/13/57	John F. Freitas	Unnamed stream	SW	NW	27	9N	5W		6.0 afa	Domestic, Irrigation, Stockwater	Permit 11379
17856	10/22/57	Patrick C. and Esther Eakle	Unnamed stream	NE	NW	27	9N	5W		2.0 afa	Domestic, Irrigation, Stockwater	Permit 11436
17979	2/6/58	George Moskowite	Unnamed stream	SE	SW	9	7N	3W		5.0 afa	Stockwater	Permit 12007
17980	2/6/58	George Moskowite	Unnamed stream	SE	SW	9	7N	3W		8.0 afa	Stockwater	Permit 12008
18165	5/29/58	Middletown Co. W. D.	Dry Creek	NE	NE	8	10N	7W		7,000 afa	Irrigation, Domestic, Recreation	Permit 11751
18405	11/12/58	Usibelli Coal Mine	Maxwell Creek	SW NE	NW NW	35 35	9N 9N	5W		1,500 afa	Irrigation, Recreation	Pending
18490	1/27/59	Harry and Marjorie J. Carlson	Unnamed stream	SE	SW	10	7N	3W		20.0 afa	Stockwater	Permit 11948
18491	1/27/59	" " " " "	" "	SE	SW	10	7N	3W		20.0 afa	Stockwater	Permit 11949
18492	1/27/59	" " " " "	" "	SE	NW	10	7N	3W		20.0 afa	Stockwater	Permit 11950
18493	1/27/59	" " " " "	" "	SW	NW	14	7N	3W		20.0 afa	Stockwater	Permit 11951
18494	1/27/59	" " " " "	" "	SW	NW	13	7N	3W		25.0 afa	Stockwater	Permit 11952
18495	1/27/59	" " " " "	" "	NE	SW	22	8N	3W		20.0 afa	Stockwater	Permit 11953
18496	1/27/59	" " " " "	" "	NE	SE	10	7N	3W		20.0 afa	Stockwater	Permit 11954

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18497	1/27/59	Harry and Marjorie J. Carlson	Unnamed stream	NE	SW	34	8N	3W		20.0 afa	Stockwater	Permit 11955
18498	1/27/59	" " " " "	" "	SE	SW	34	8N	3W		20.0 afa	Stockwater	Permit 11956
18499	1/27/59	" " " " "	" "	NE	SE	34	8N	3W		20.0 afa	Stockwater	Permit 11957
18500	1/27/59	" " " " "	" "	NW	SE	22	8N	3W		20.0 afa	Stockwater	Permit 11958
18501	1/27/59	" " " " "	" "	SW	SW	22	8N	3W		20.0 afa	Stockwater	Permit 11959
18502	1/27/59	" " " " "	" "	SE	NW	23	7N	3W		20.0 afa	Stockwater	Permit 11960
18503	1/27/59	" " " " "	" "	SE	NW	34	8N	3W		20.0 afa	Stockwater	Permit 11961
18504	1/27/59	" " " " "	" "	NW	SW	12	7N	3W		20.0 afa	Stockwater	Permit 11962
18505	1/27/59	" " " " "	Wragg Creek	NE	NE	14	7N	3W		20.0 afa	Stockwater	Permit 11963
18506	1/27/59	" " " " "	Unnamed stream	SE	NE	28	8N	3W		20.0 afa	Stockwater	Permit 11964
18507	1/27/59	" " " " "	East Mitchel Canyon	NW	NW	12	7N	3W		20.0 afa	Stockwater	Permit 11965
18510	1/29/59	George Moskowite	Unnamed stream	NW	NE	21	7N	3W		10.0 afa	Domestic, Irrigation Recreation, Stockwater	Permit 11896
18613	3/27/59	Alden M. and Ella Spiers	Unnamed stream	NW	SE	5	11N	7W		0.25 cfs 6.0 afa	Domestic, Recreation	Pending
			Big Canyon Creek	NW	SW					0.25cfs 6.0 afa		
18647	4/15/59	Usibelli Coal Mine	Maxwell Creek	SE	SW	26	9N	5W		500 afa	Irrigation, Recreation	Pending
18834	6/29/59	Frank E. Gross	Unnamed creek	SE SE	SW SW	10	10N	7W		14.0 afa	Irrigation	Permit 12330
18866	7/21/59	George H. and Juanita Langford	Capell Creek Middle Creek	NW NW	SW SW	6 7	7N 7N	3W 3W		0.9 cfs 0.1 cfs 47.0 afa	Irrigation, Domestic, Stockwater, Recreation	Permit 12190
18925	8/19/59	Sugar Loaf Hunting Club	Unnamed creek	NW	NW	18	8N	3W		40.0 afa	Stockwater, Recreation	Permit 12239
18939	8/26/59	Arthur P. and Barbara Wandtke, Jr.	Unnamed stream	NW	NE	1	9N	6W		48.0 afa	Irrigation, Stockwater, Recreation	Permit 12212
18949	8/28/59	Donald N. Duvall	Unnamed stream	NW	SE	12	9N	6W		47.0 afa	Domestic, Stockwater, Irrigation	Permit 12287
19074	11/9/59	W. Kenneth and Marjorie Gaffney	2 Unnamed streams	NW SW	SW SW	36	10N	6W		20.0 afa	Irrigation, Recreation	Permit 12343
19127	12/9/59	Donald N. Duvall	Unnamed stream	NW	NW	18	9N	5W		200.0 afa	Irrigation, Stockwater	Pending
19318	3/23/60	Hazen A. Dennis	Unnamed stream	NE	NE	5	10N	7W		35.0 afa	Irrigation, Stockwater	Pending
19374	4/21/60	Donald N. Duvall	Unnamed stream	NE NW	SW SW	12	9N	6W		70.0 afa	Irrigation, Stockwater, Recreation, Domestic	Pending
19501	6/22/60	Leroy E. and Wilma Gray	Unnamed stream	SE	NW	16	7N	3W		140.0 afa	Irrigation, Recreation	Pending
19567	7/21/60	Col. William E. and Geraldine F. Zuerner	Unnamed stream	SE	SE	36	10N	6W		10.0 afa	Stockwater, Irrigation, Recreation	Pending
19582	7/26/60	Ralph W. Johnson and William F. Bottoms	Unnamed stream	NE	NE	18	10N	6W		49.0 afa	Domestic, Irrigation, Recreation	Pending
19656	8/12/60	Charles E. H. and Hazel Runge	Unnamed stream	NE	SE	6	9N	5W		4.0 afa	Domestic, Irrigation, Recreation	Permit 12845

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19884	12/20/60	Louis Gregoris and Ronald L. Ferry	Jericho Creek tributary to Hunting Creek	SW	NE	5	11N	5W	MD	0.38 cfs 5 afa	Irrigation	Pending
19885	12/20/60	Louis Gregoris and Ronald L. Ferry	Hunting Creek tributary to Putah Creek	SE	NE	15	11N	5W	MD	0.63 cfs	Irrigation	Pending
19890	12/21/60	Investment Operating Corporation	Bucksnort Creek	SE	SE	9	10N	6W	MD	12.53 cfs 3802.5 afa	Irrigation, Stockwater	Pending
19909	1/9/61	Josiah N. Rhodes and Jessie K. Connell	Smittle Creek tributary to Putah Creek	SE	SE	35	9N	4W	MD	1416 afa	Domestic, Recreation, Stockwater	Pending
19914	1/11/61	Crescent Park Realty Company	Capell Creek	SE	SW	29	7N	3W	MD	1 cfs 1100 afa	Irrigation, Recreation, Fish Culture	Pending
19934	1/27/61	U. S. Bureau of Reclamation	Putah Creek	SW	NE	29	8N	2W	MD	20 cfs 7500 afa	Municipal, Domestic, Stockwater	Pending
19964	2/6/61	Myron D. and Evelyn I. Walker	Unnamed stream	SW	SW	9	10N	4W	MD	5 afa	Stockwater	Incomplete
20042	3/20/61	Norman B. Livermore and Sons	Unnamed stream tributary to St. Helena Creek	NE	NE	36	10N	7W	MD	125 afa	Irrigation, Domestic, Recreation, Fish Culture	Incomplete
20060	3/30/61	California Leisure Lands, Inc.	(1) Unnamed stream tributary to Pope Creek	NW	SW	9	9N	5W	MD	100 afa	Irrigation, Domestic, Industrial, Recreation, Stockwater	Incomplete
			(2) Pope Creek tributary to Putah Creek	SW	SE	9	9N	5W	MD	400 afa		
20061	3/30/61	Dick Week	Pope Creek	SE	SW	10	9N	5W	MD	500 afa	Irrigation, Domestic, Industrial, Recreation, Stockwater	Incomplete
20107	5/3/61	George Moskowite	Unnamed stream tributary to Capell Creek	SW	SW	34	7N	3W	MD	400 afa	Irrigation, Domestic, Recreation, Stockwater, Fish culture and Fire protection	Incomplete
20145	5/23/61	E. N. and Illa M. Faria	Collayomi Brook tributary to Putah Creek	SW	NE	14	11N	8W	MD	1800 gpd	Domestic	Incomplete
20152	5/31/61	Manuel and Gladyes Dutra	(1) Unnamed stream	NE	NE	25	7N	4W	MD)		Irrigation, Stockwater	Pending
			(2) Unnamed stream	SE	NE	25	7N	4W	MD)	- 85 afa		
			(3) Capell Creek	SW	NE	30	7N	3W	MD)			
20335	7/31/61	Rufino Fernandes	Cassidy Creek tributary to Bucksnort Creek	NW	SW	22	10N	6W	MD	35 afa	Irrigation, Stockwater, Recreation	Incomplete
20370	8/29/61	James M. and James H. Conner	(1) Unnamed stream tributary to Pope Creek	NE	SW	11	9N	5W	MD	35 afa	Irrigation, Stockwater	Incomplete
			(2) Pope Creek tributary to Putah Creek	SW	SE	11	9N	5W	MD	0.25 cfs		
20371	8/29/61	James M. and James H. Conner	Spring tributary to unnamed stream thence Pope Creek	SE	SE	2	9N	5W	MD	778 gpd	Domestic, Stockwater	Incomplete

APPENDIX B

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BIBLIOGRAPHY

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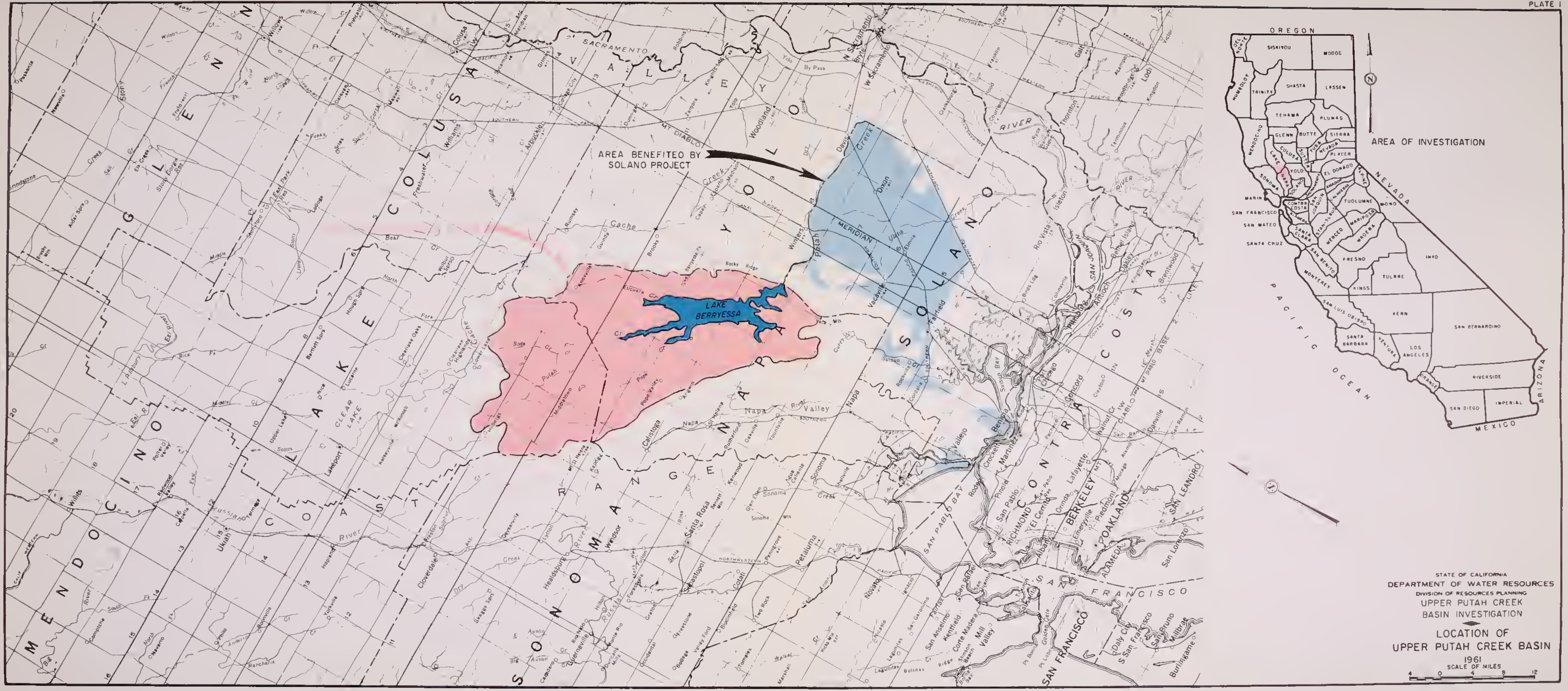


STATE OF CALIFORNIA
DEPARTMENT OF WATER RESOURCES
DIVISION OF RESOURCES PLANNING
UPPER PUTAH CREEK
BASIN INVESTIGATION

LOCATION OF
UPPER PUTAH CREEK BASIN
1961

SCALE OF MILES

LEGEND

PRESENTLY DEVELOPED LANDS REQUIRING WATER SERVICE

URBAN AND SUBURBAN LANDS

RECREATIONAL LANDS

IRRIGATED AGRICULTURAL LANDS

CLASSIFICATION OF POTENTIALLY IRRIGABLE LAND GROUPS

VALLEY OR SLIGHTLY UNDULATING LANDS
WITH SOILS COMPRISING MEDIUM TO DEEP EFFECTIVE ROOT ZONES AND SUITABLE FOR ALL CLIMATICALLY ADAPTED CROPS

VALLEY OR SLIGHTLY UNDULATING LANDS
WITH LIMITED CROP ADAPTABILITY DUE TO SHALLOW DEPTH OF EFFECTIVE ROOT ZONE OR TO PRESENCE OF ROCK IN PLOW ZONE

GENTLY TO STEEPLY SLOPING AND ROLLING HILL LANDS
WITH SOILS COMPRISING MEDIUM TO DEEP EFFECTIVE ROOT ZONES SUITABLE FOR ALL CLIMATICALLY ADAPTED CROPS AND LIMITED ONLY BY EASE OF DEVELOPMENT IMPOSED BY TOPOGRAPHIC CONDITIONS

GENTLY TO STEEPLY SLOPING AND ROLLING HILL LANDS
WITH LIMITED CROP ADAPTABILITY DUE TO SHALLOW DEPTH OF EFFECTIVE ROOT ZONE AND PRESENCE OF ROCK IN THE PLOW ZONE AND ALSO LIMITED BY EASE OF DEVELOPMENT IMPOSED BY TOPOGRAPHIC CONDITIONS

MIDDLETOWN COUNTY WATER DISTRICT BOUNDARY

STATE OF CALIFORNIA
DEPARTMENT OF WATER RESOURCES
DIVISION OF RESOURCES PLANNING
UPPER PUTAH CREEK BASIN INVESTIGATION

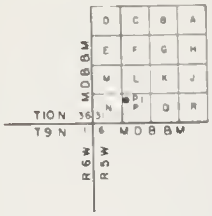
LAND USE AND CLASSIFICATION 1961

SCALE OF MILES
2 3 4

PLATE 2


LEGEND
PRESENTLY DEVELOPED LANDS REQUIRING WATER SERVICE
URBAN AND SUBURBAN LANDS
RECREATIONAL LANDS
IRRIGATED AGRICULTURAL LANDS
CLASSIFICATION OF POTENTIALLY IRRIGABLE LAND GROUPS
VALLEY OR SLIGHTLY UNDULATING LANDS
VALLEY OR SLIGHTLY UNDULATING LANDS
GENTLY TO STEEPLY SLOPING AND ROLLING HILL LANDS
GENTLY TO STEEPLY SLOPING AND ROLLING HILL LANDS
MIDDLETOWN COUNTY WATER DISTRICT BOUNDARY
STATE OF CALIFORNIA
DEPARTMENT OF WATER RESOURCES
DIVISION OF RESOURCES PLANNING
UPPER PUTAH CREEK BASIN INVESTIGATION
LAND USE
AND CLASSIFICATION
1961
SCALE OF MILES
LAKE BERRYESSA
POPE VALLEY
COYOTE VALLEY
LONG VALLEY
PUTAH CREEK
LAKE NAPA
T12N
T11N
T10N
T9N
T8N
T7N
R8W
R7W
R6W
R5W
R4W
R3W

KEY TO WELL NUMBERING SYSTEM



WELLS SHOWN ARE NUMBERED BY TOWNSHIP, RANGE, AND SUBDIVISION OF SECTION e g T10N/R5W-31P1 (TO FACILITATE WELL NUMBERING, US LAND SURVEY SECTION LINES WERE EXTENDED THROUGHOUT LAND GRANT AREAS)

STATE OF CALIFORNIA
DEPARTMENT OF WATER RESOURCES
DIVISION OF RESOURCES PLANNING
UPPER PUTAH CREEK BASIN INVESTIGATION

LOCATIONS OF WELLS
CANVASSED
1961

SCALE OF MILES
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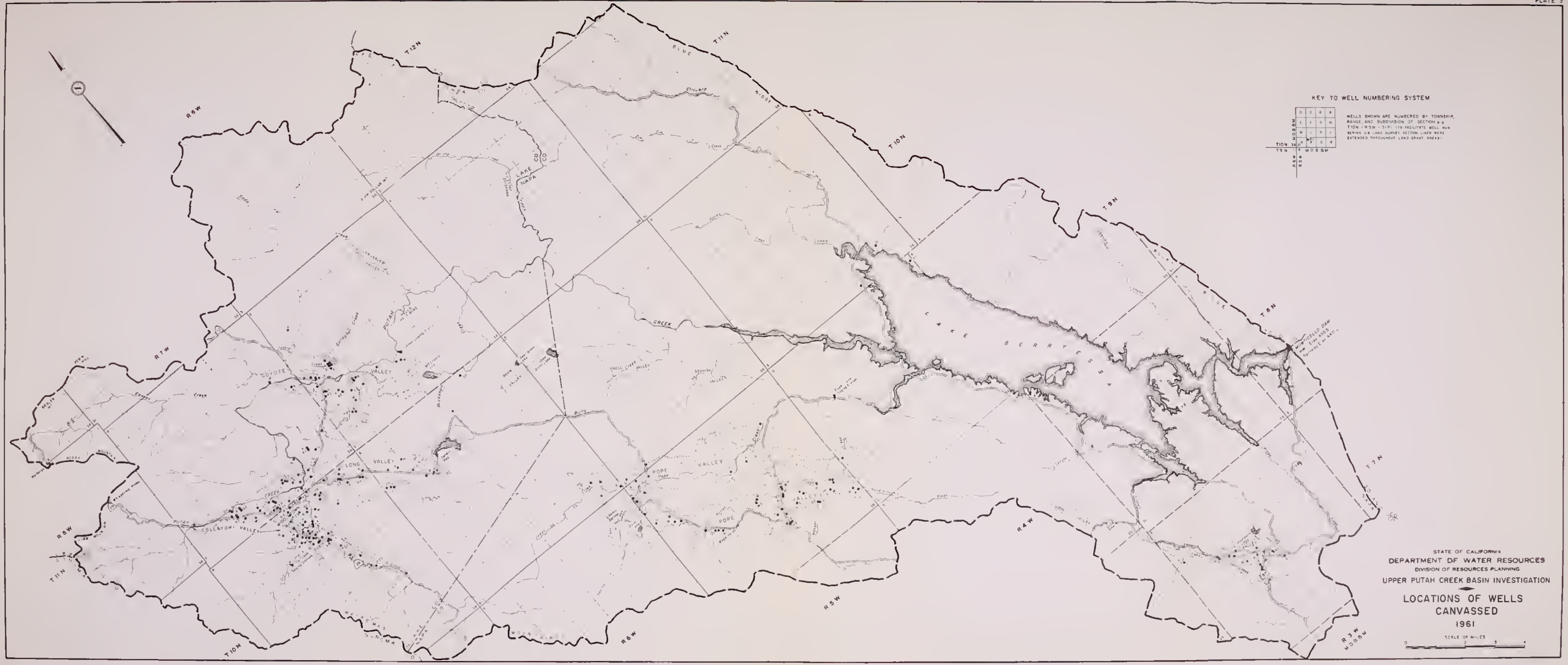
KEY TO WELL NUMBERING SYSTEM
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POPE VALLEY
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COYOTE VALLEY
COLLAYOMI VALLEY
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R5W
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STATE OF CALIFORNIA
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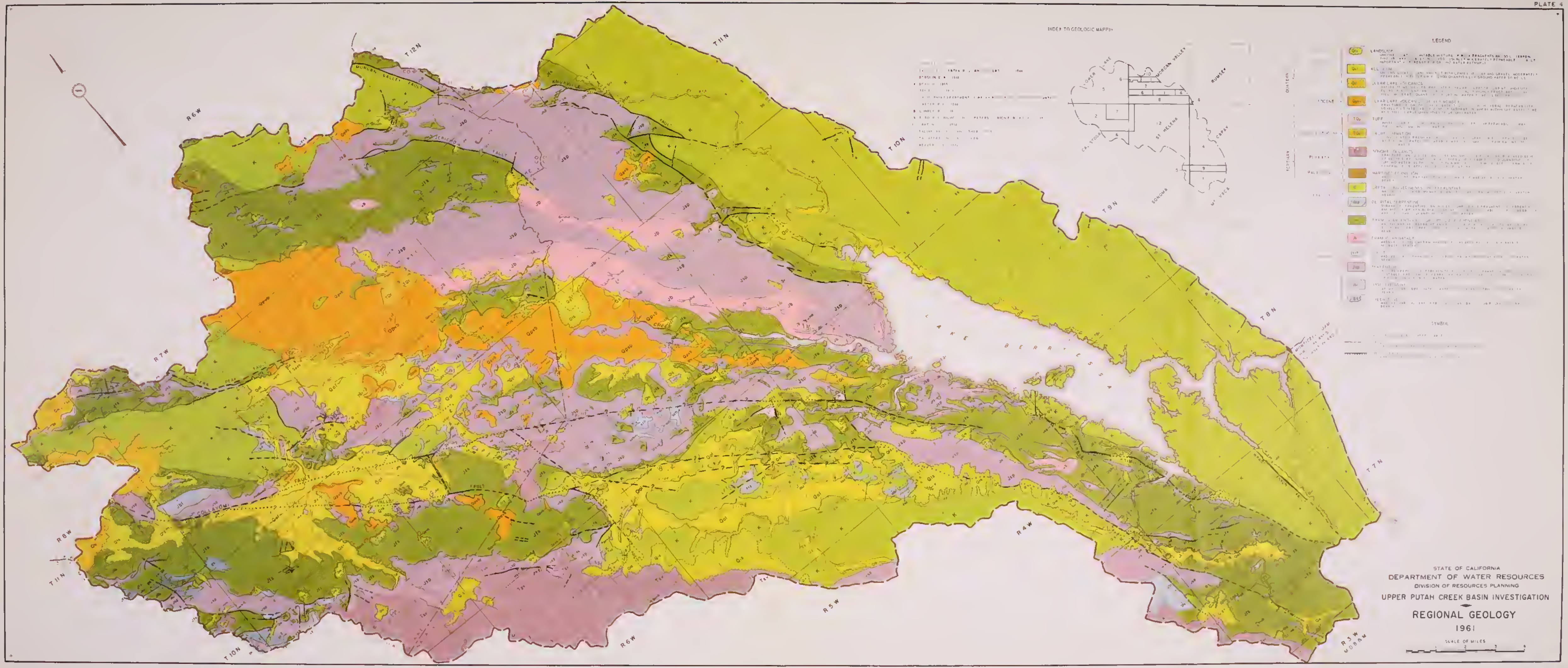
DIVISION OF RESOURCES PLANNING
UPPER PUTAH CREEK BASIN INVESTIGATION
LOCATIONS OF WELLS
CANVASSED
1961
SCALE OF MILES

PLATE 4



INDEX TO GEOLOGIC MAPPING
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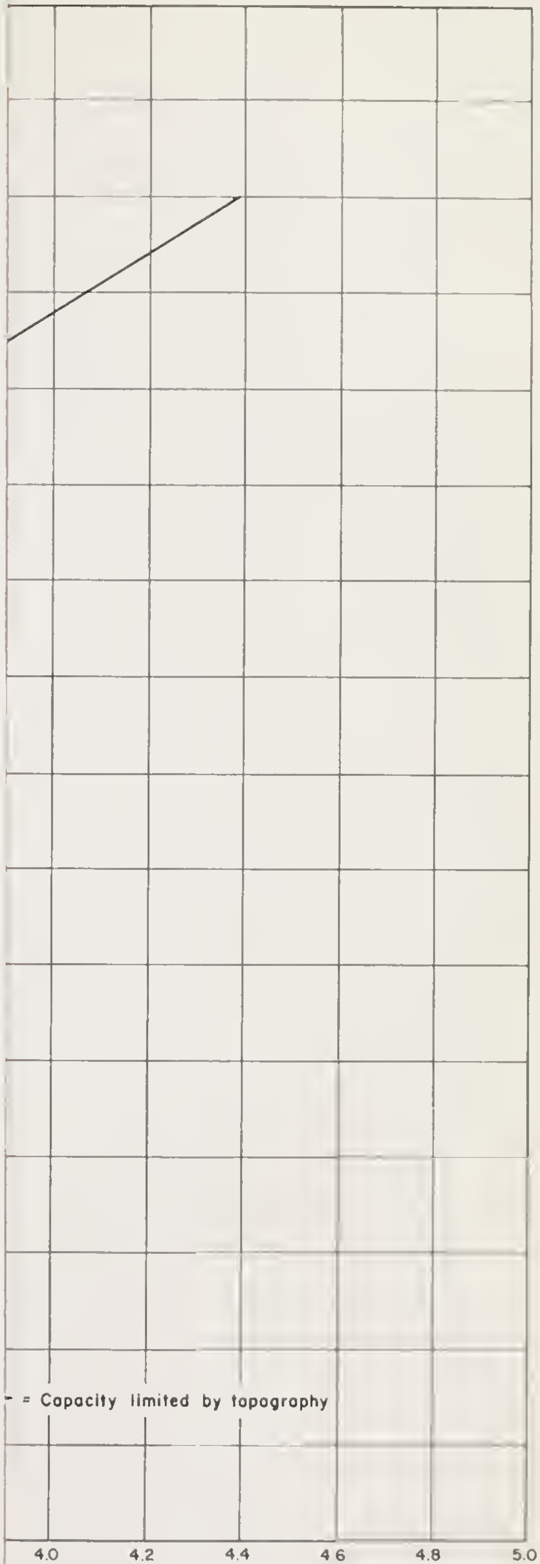
TUFF
SYMBOL
LAKE BERRYESSA
MONTICELLO DAM
T 12 N
T 11 N
T 10 N
T 9 N
T 8 N
T 7 N
R 8 W
R 7 W
R 6 W
R 5 W
R 4 W
R 3 W
M.D.B.&M.
STATE OF CALIFORNIA
DEPARTMENT OF WATER RESOURCES
DIVISION OF RESOURCES PLANNING
UPPER PUTAH CREEK BASIN INVESTIGATION
REGIONAL GEOLOGY
1961
SCALE OF MILES



COST


STATE OF CALIFORNIA
DEPARTMENT OF WATER RESOURCES
DIVISION OF RESOURCES PLANNING
UPPER PUTAH CREEK BASIN INVESTIGATION
LOCATIONS OF
DAM AND RESERVOIR SITES
1961
SCALE OF MILES
LAKE BERRYESSA
ADAMS RES
COYOTE CREEK RES
MIDDLETOWN RES
WALTER SPRINGS RES
GOODINGS RES
JAMES CREEK RES
DRY CREEK RES
PUTAH CREEK CANYON RES
DIVERSION CANAL
LONG VALLEY
POPE VALLEY
COYOTE VALLEY
MIDDLETOWN
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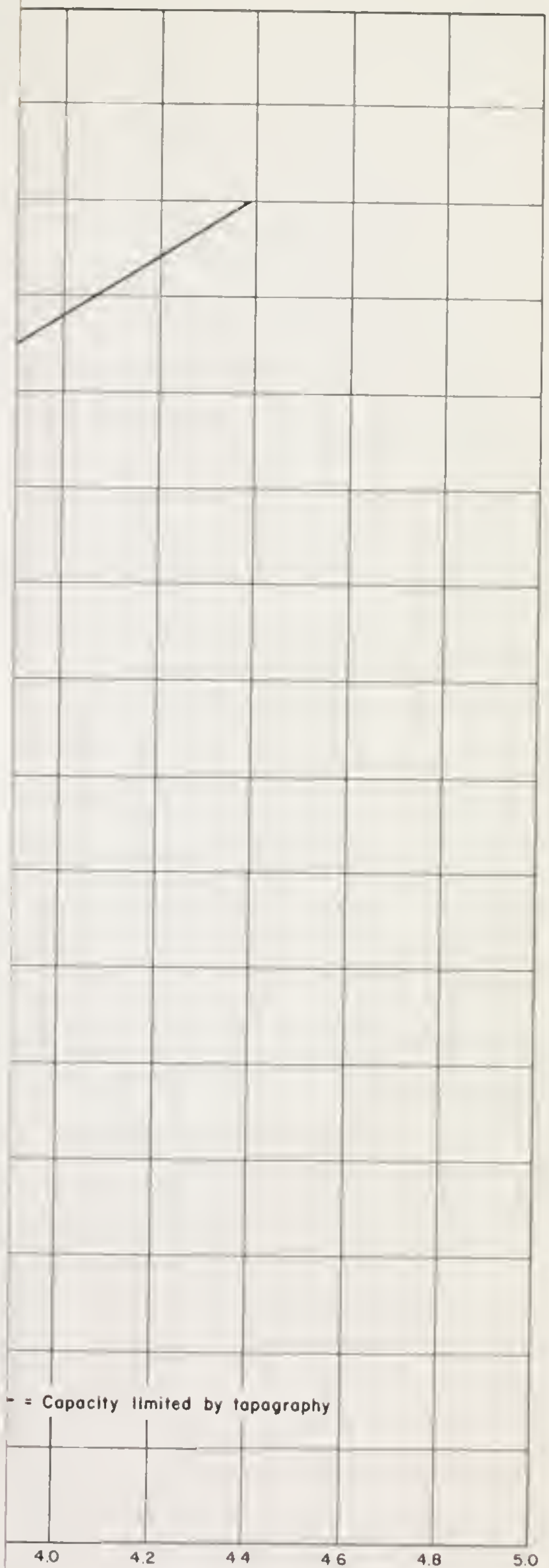

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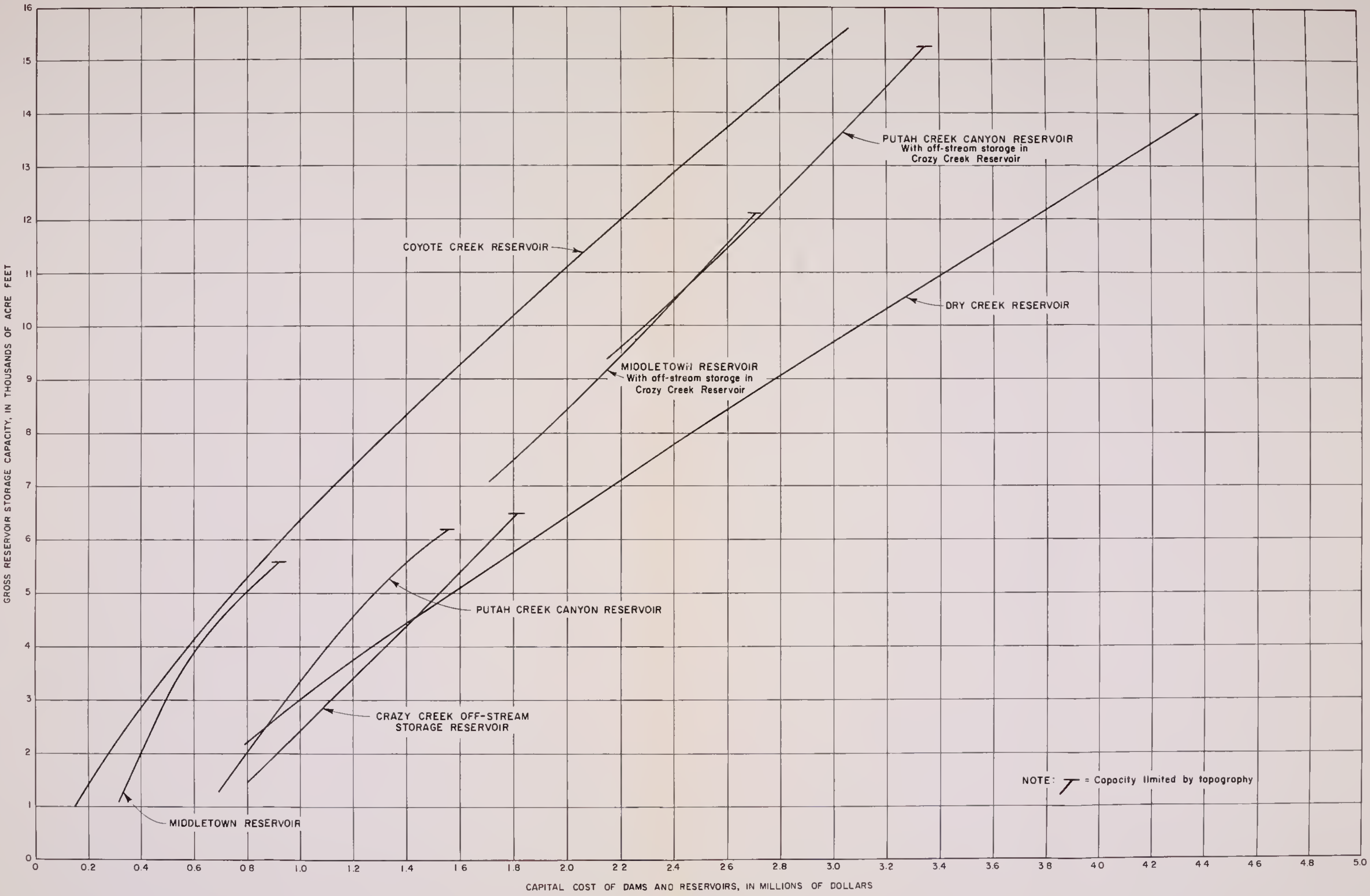

RECONNAISSANCE ESTIMATES OF RELATIONSHIPS BETWEEN STORAGE CAPACITY AND CAPITAL COST
FOR
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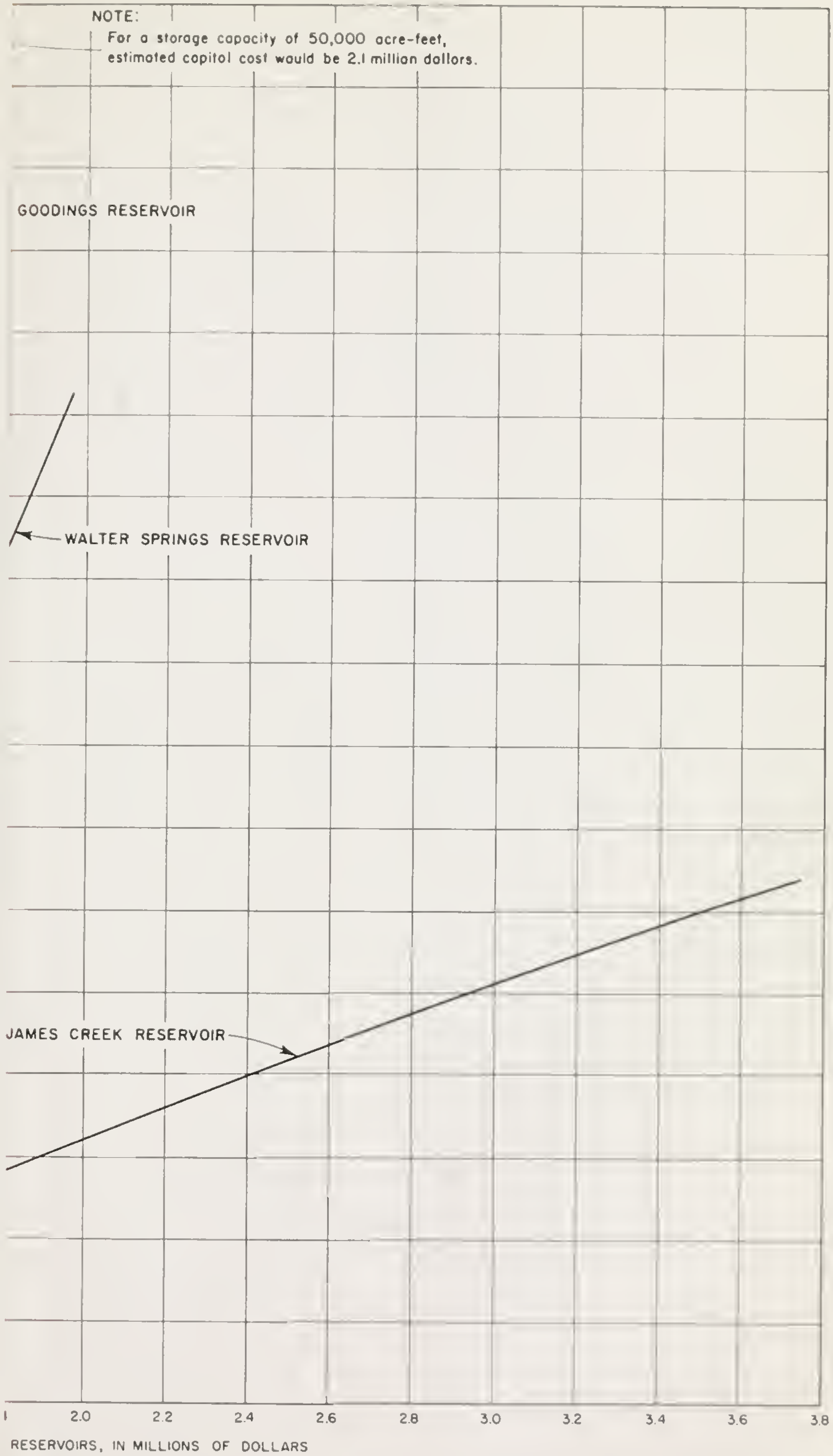
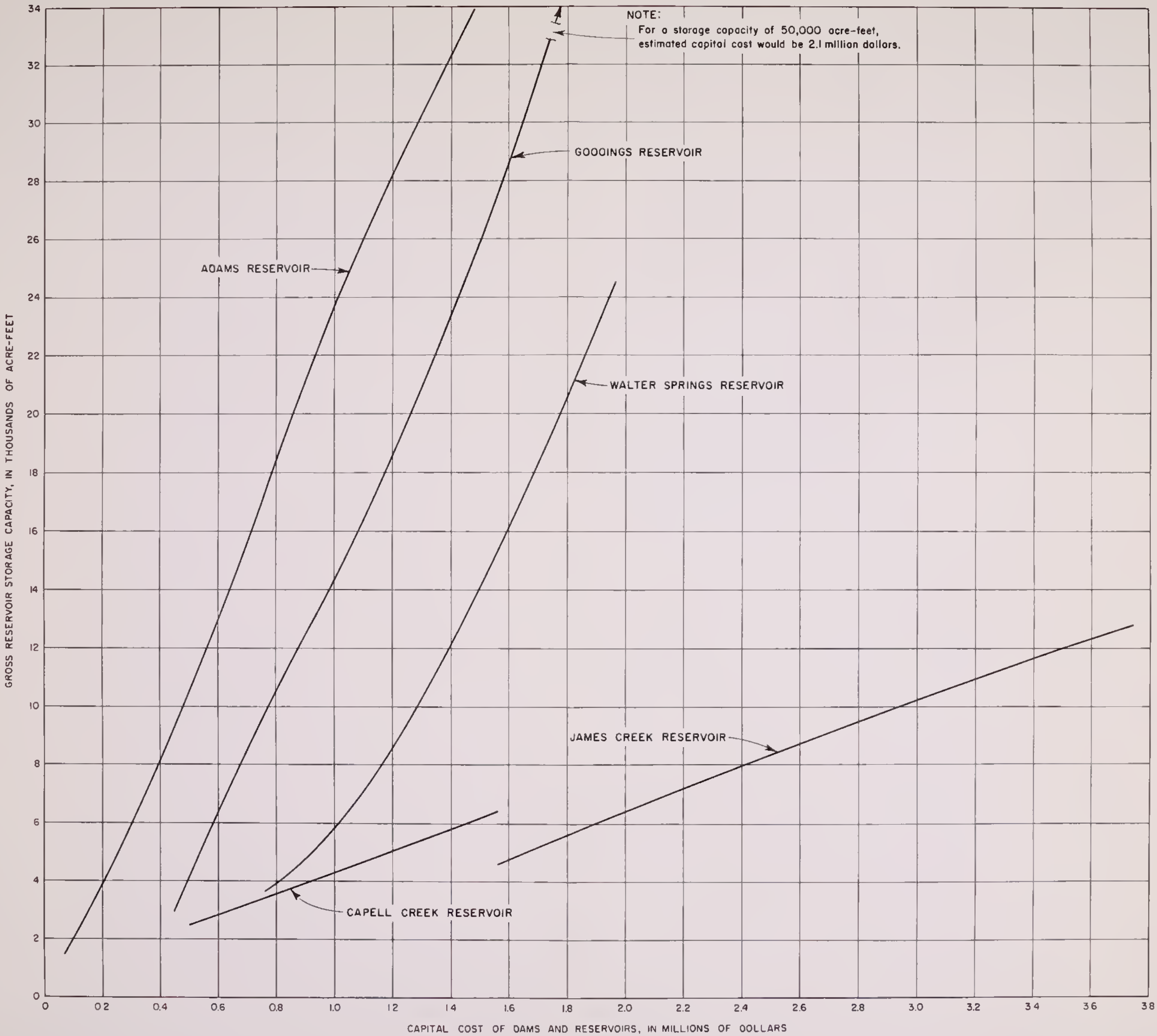


3ETWEEN STORAGE CAPACITY AND CAPITAL COST
IN NAPA COUNTY



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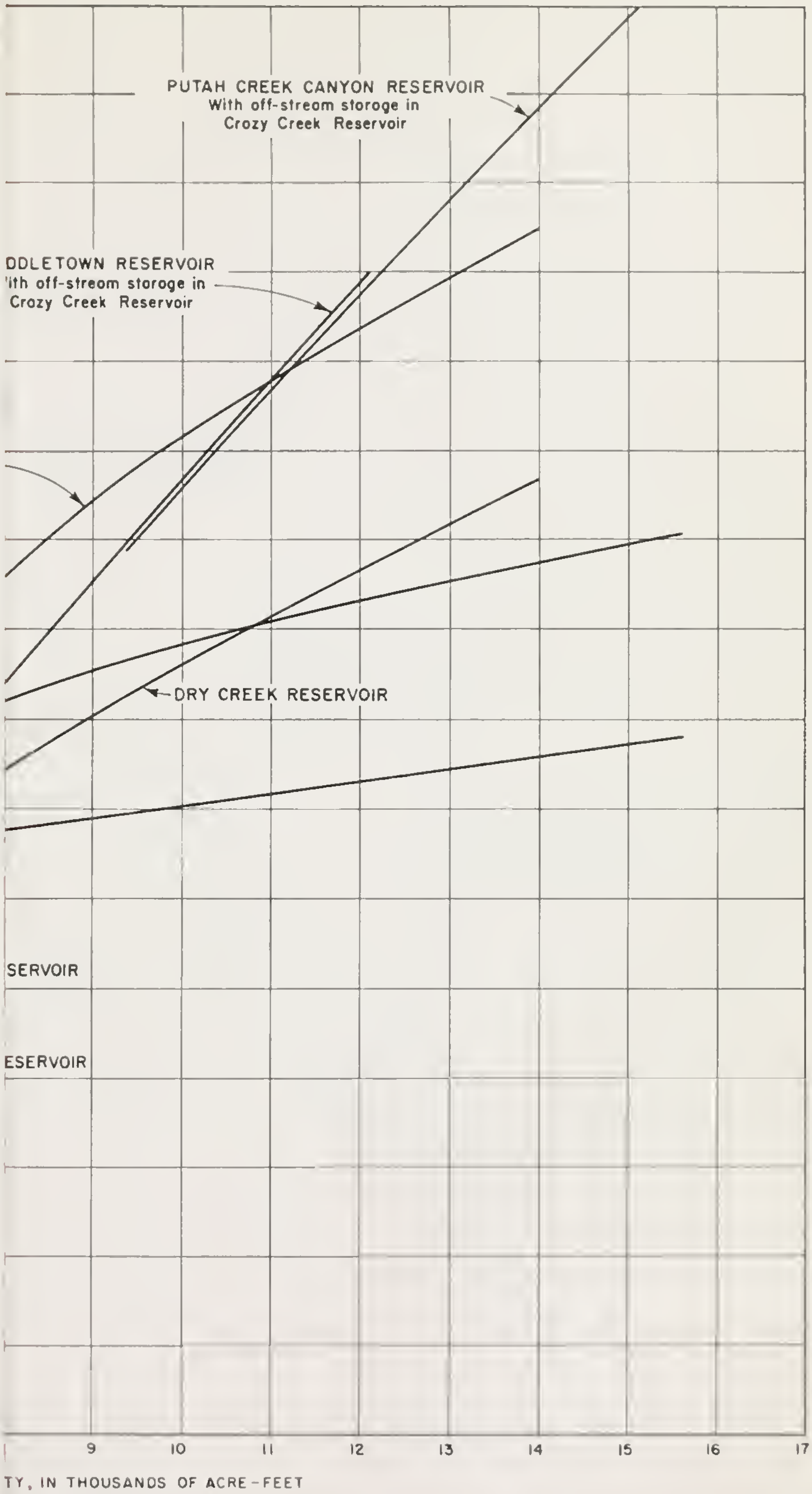
DEPARTMENT OF WATER RESOURCES 1961



BETWEEN ANNUAL YIELD AND STORAGE CAPACITY
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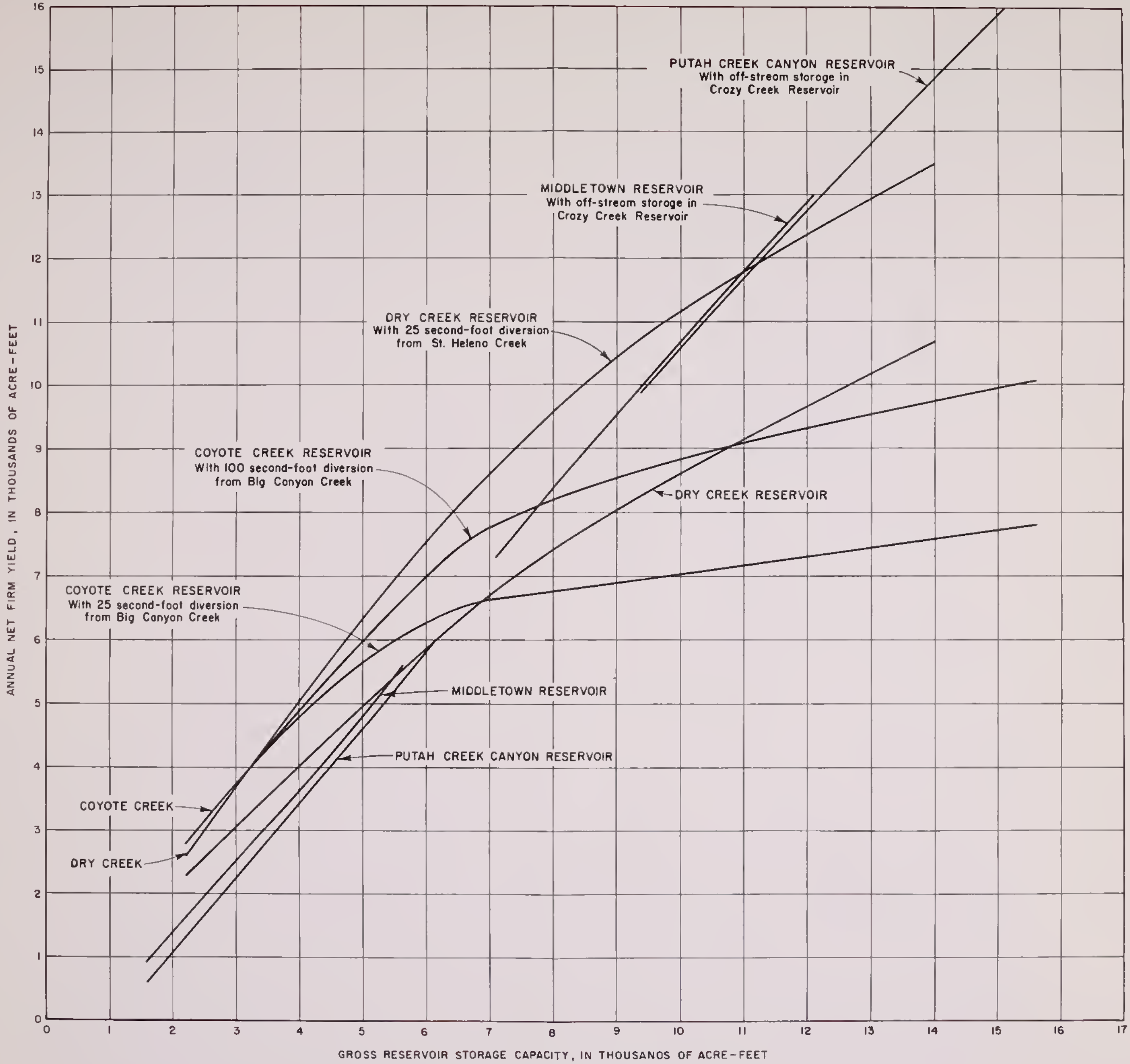
LAKE COUNTY



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FOR
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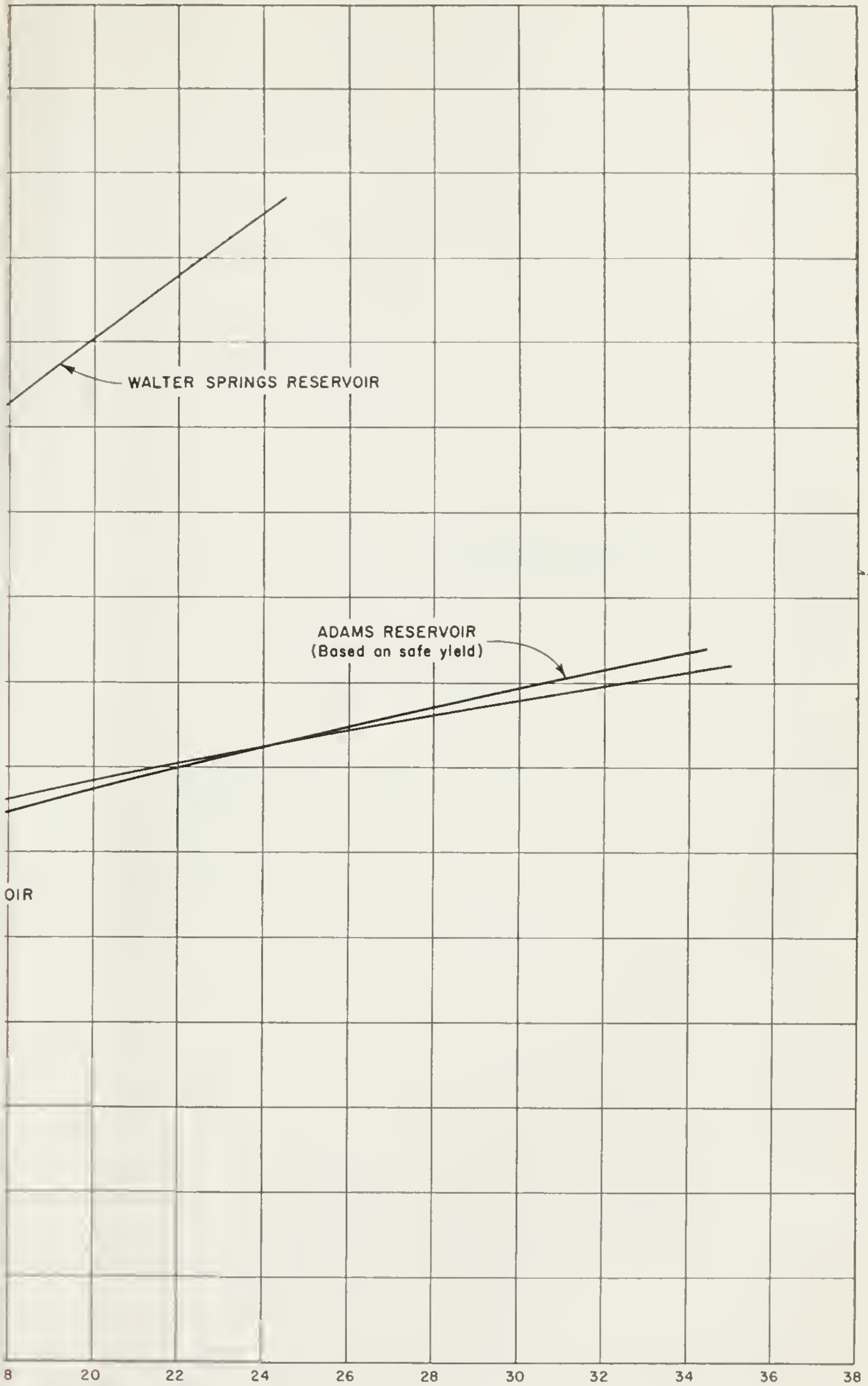
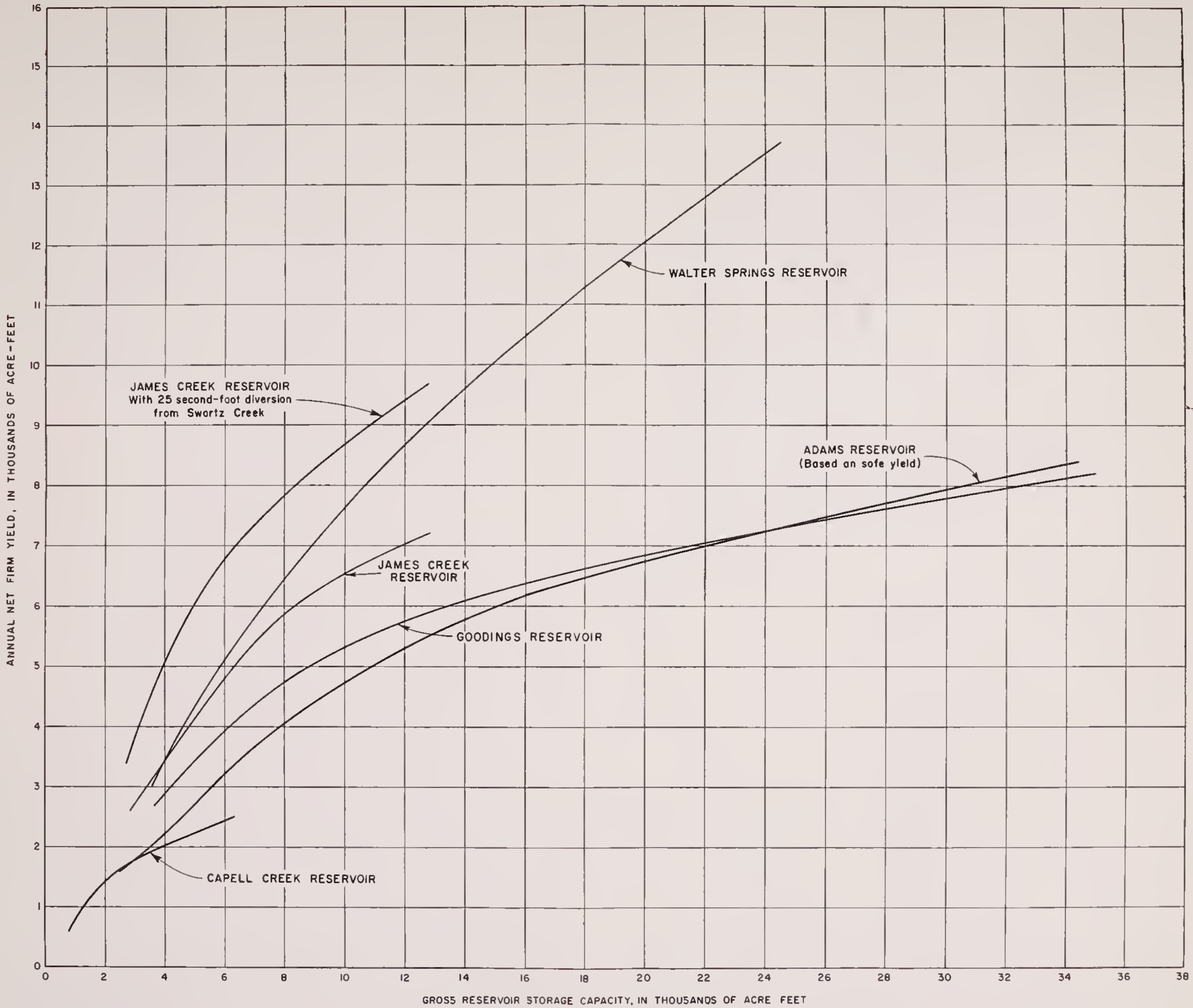


BETWEEN ANNUAL YIELD AND STORAGE CAPACITY
OR
NAPA COUNTY



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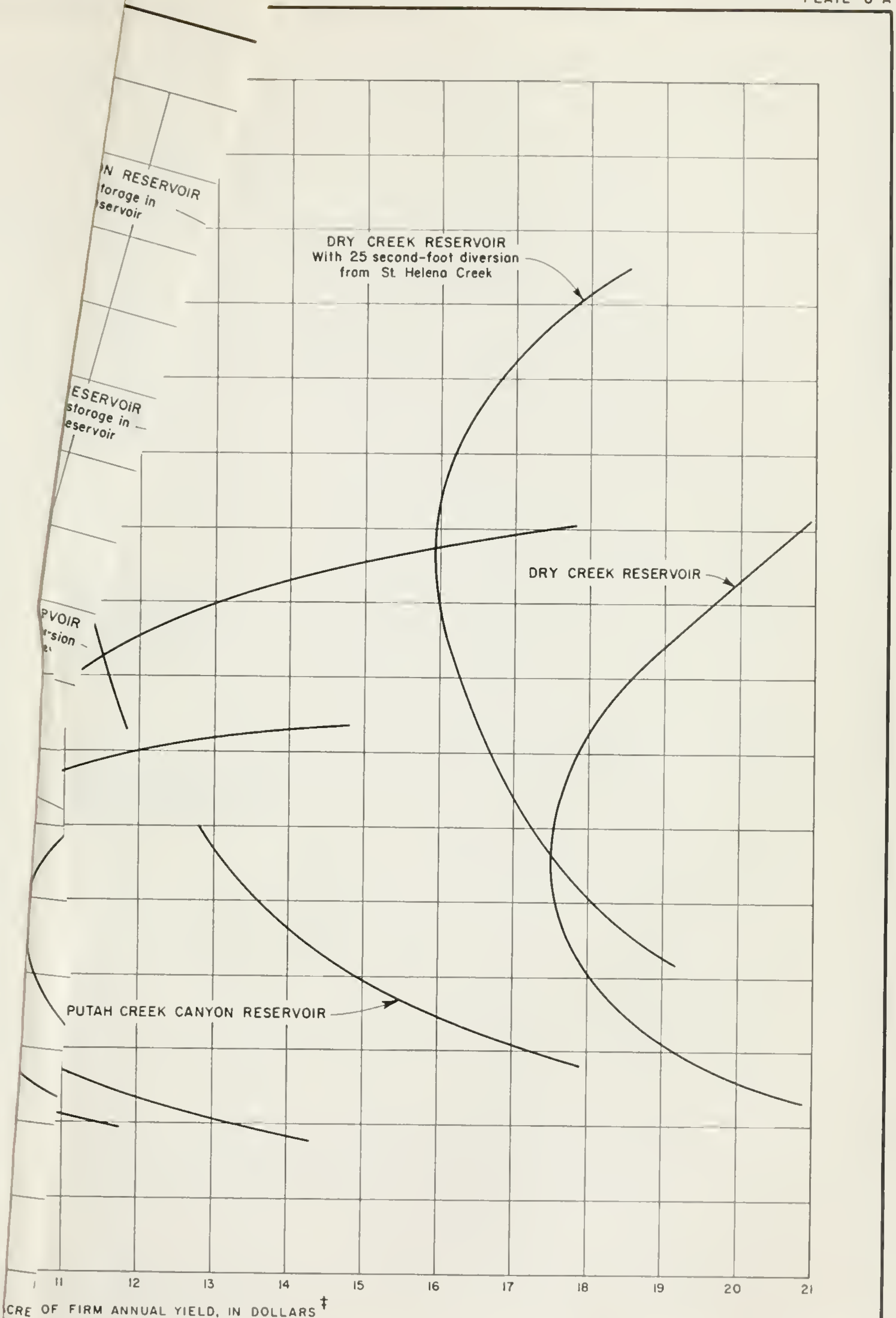
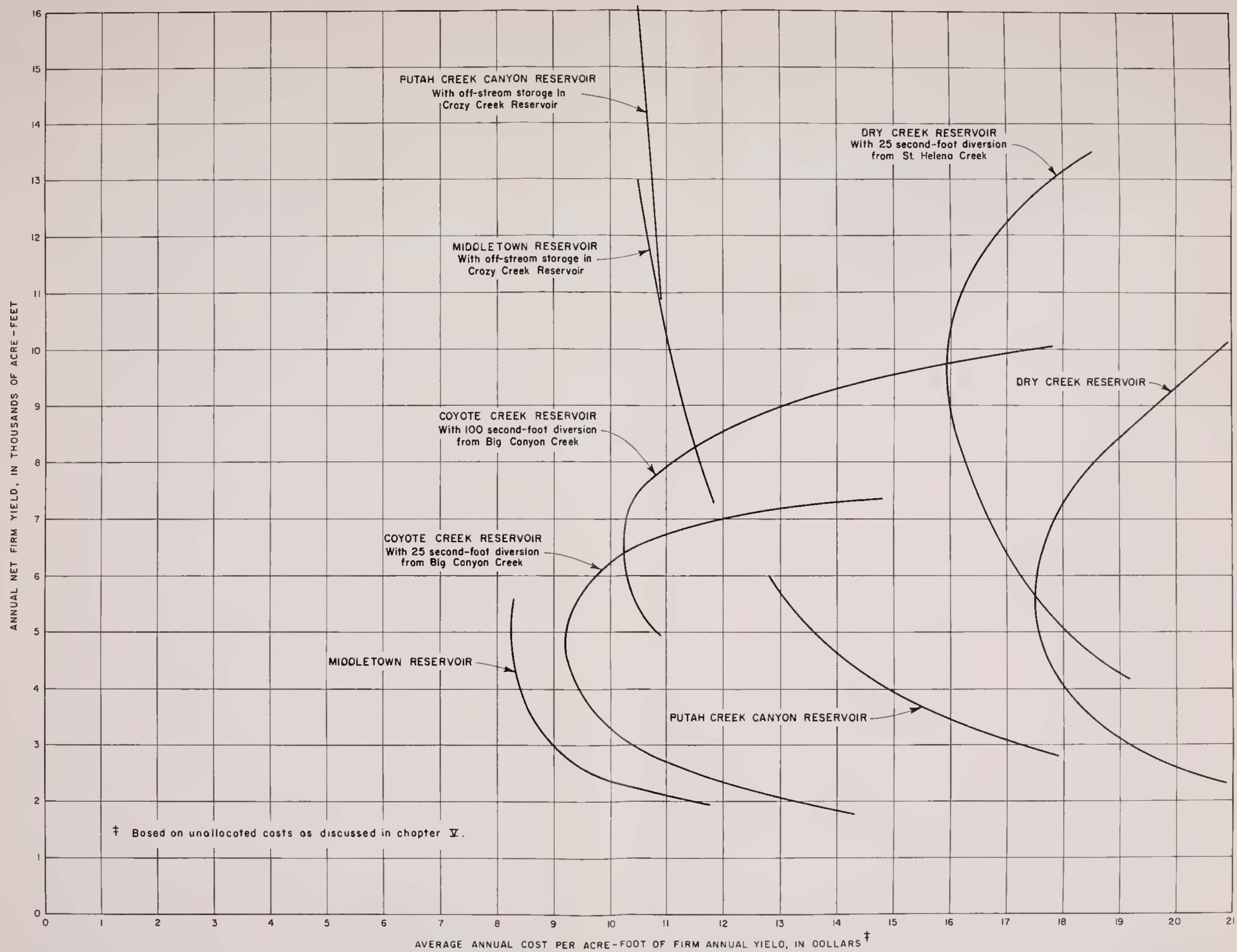
FOR
RESERVOIRS IN NAPA COUNTY

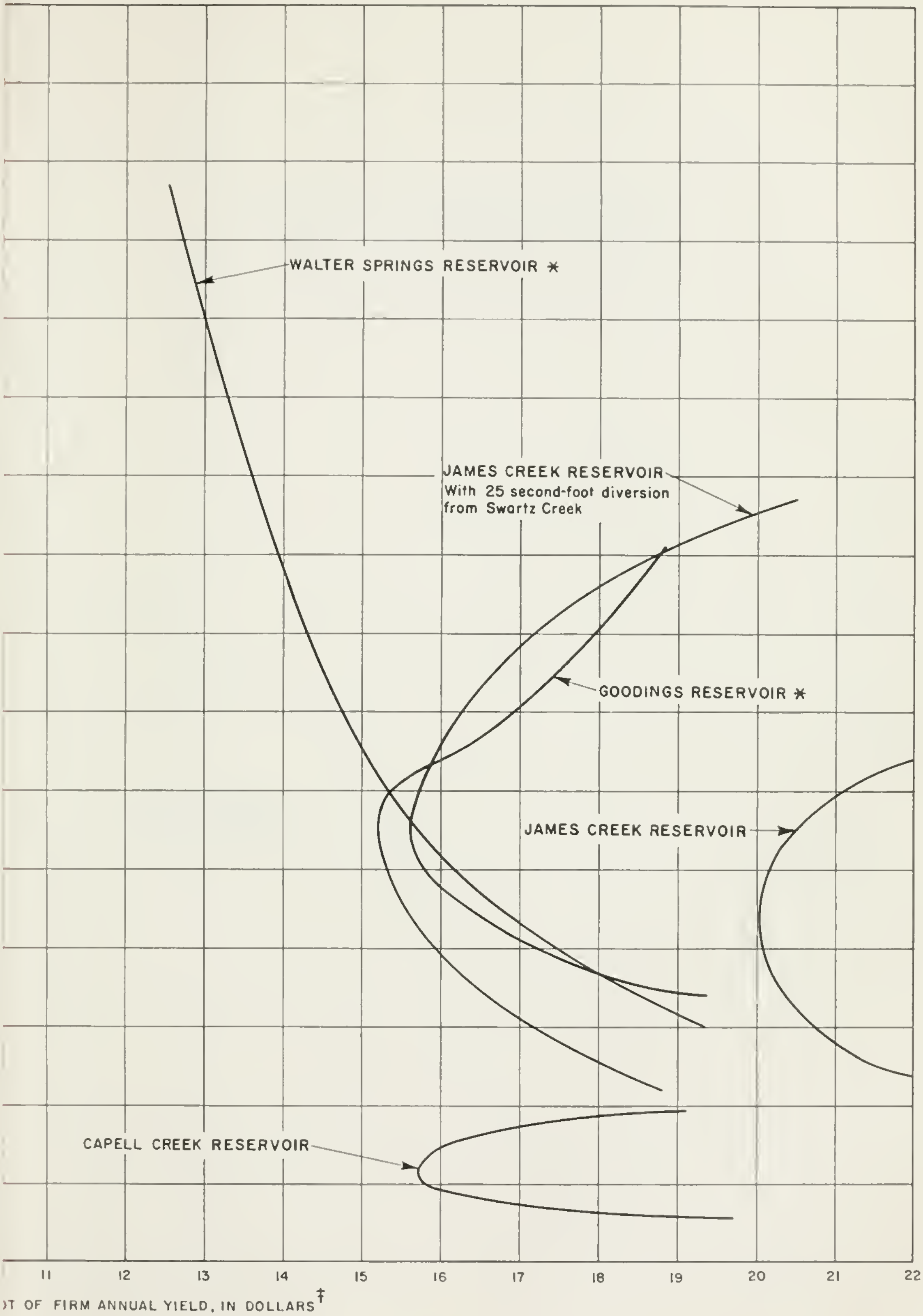


EWEEN ANNUAL YIELD AND UNIT COST

LAKE COUNTY



RECONNAISSANCE ESTIMATES OF RELATIONSHIPS BETWEEN ANNUAL YIELD AND UNIT COST
OF
WATER FOR RESERVOIRS IN LAKE COUNTY



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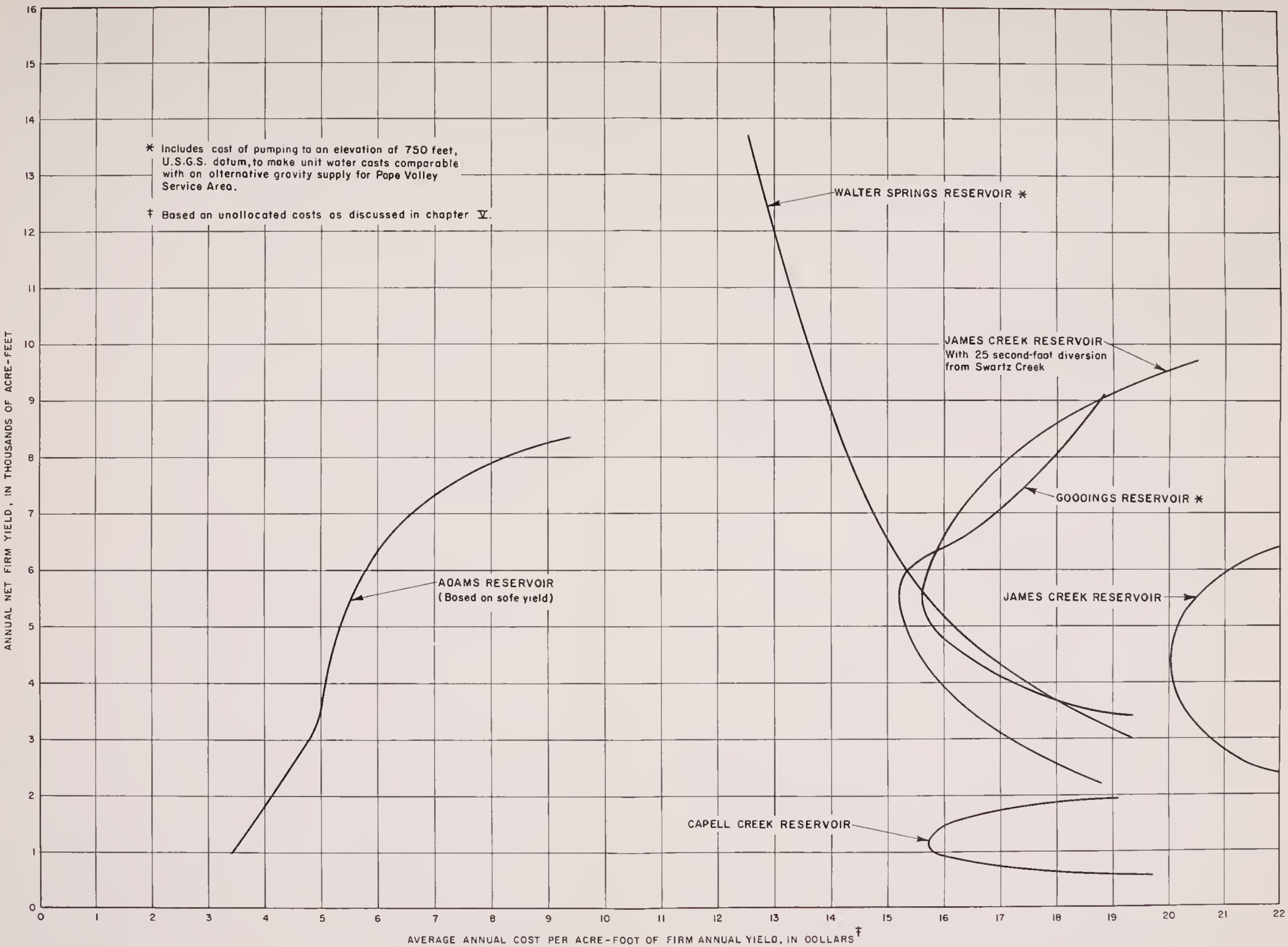

RECONNAISSANCE ESTIMATES OF RELATIONSHIPS BETWEEN ANNUAL YIELD AND UNIT COST OF WATER FOR RESERVOIRS IN NAPA COUNTY

DEPARTMENT OF WATER RESOURCES 1961

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